

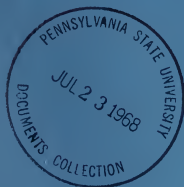
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FEASIBILITY STUDY OF

CHEMICAL INDUSTRY

IN

SOUTHWESTERN PENNSYLVANIA



in two volumes

VOLUME 1

Synthetic Abrasives
Polyvinyl Chloride Plant

U.S. DEPARTMENT OF COMMERCE
Alexander B. Trowbridge, Secretary
Ross D. Davis, Assistant Secretary
for Economic Development



ECONOMIC DEVELOPMENT ADMINISTRATION

TECHNICAL
ASSISTANCE
PROJECT

U.S. DEPARTMENT OF COMMERCE

FEASIBILITY STUDY OF CHEMICAL INDUSTRY
IN
SOUTHWESTERN PENNSYLVANIA

PHASE III

SYNTHETIC ABRASIVES

September 1966

"This technical assistance study was accomplished by professional consultants under contract with the Economic Development Administration. The statements, findings, conclusions, recommendations, and other data in this report are solely those of the contractor and do not necessarily reflect the views of the Economic Development Administration."


Prepared By:

SINGMASTER & BREYER
235 East 42nd Street
New York, N.Y. 10017



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I. REPORT IN BRIEF

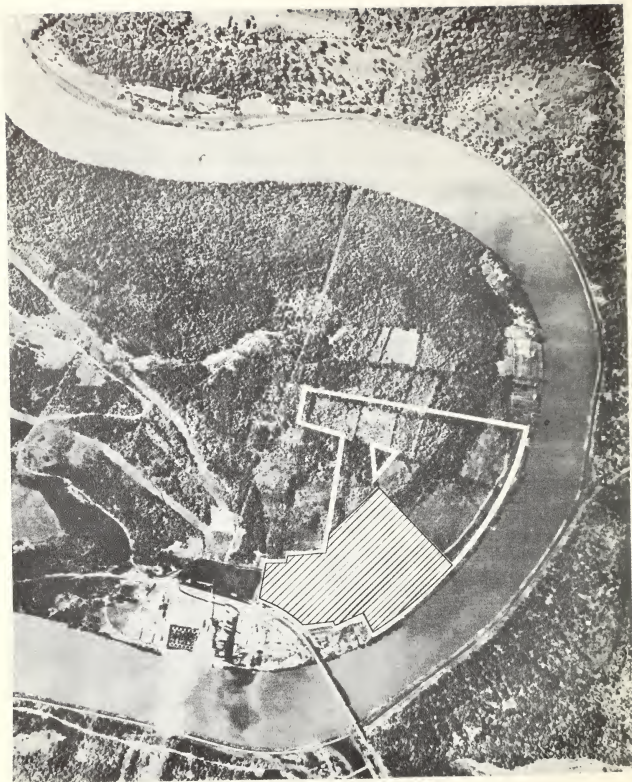
A preliminary design of a synthetic abrasives plant has been prepared for the 100-acre site near Reesedale in Armstrong County of southwestern Pennsylvania (see aerial photograph on page I-1a). Approximately 10 percent of the total annual output of both Canada and the United States was selected for the nominal design capacity:

<u>Non-Metallic Abrasive Regular Grade</u>	<u>Annual Output, Tons per Year</u>
Silicon Carbide	12,500
Fused Aluminum Oxide	25,000

The proximity of the Reesedale power plant, providing 17,500 kilowatts of electric power at a rate of 5.0 mills on an interruptible basis, is one reason for considering the manufacture of synthetic abrasives at this location. Virgin grain of the two non-metallic abrasives can be manufactured at Reesedale for about the same price as delivered crude grain from Canada:

<u>Synthetic Abrasive Virgin Grain</u>	<u>Reesedale Plant Operating Cost, \$/Ton</u>
Silicon Carbide	\$157.19
Fused Alumina	\$111.17

A total investment of \$7.082 million would be required for the crude abrasives plant. It cannot be justified, how-



RESEDALE SITE
SYNTHETIC ABRASIVES PLANT

ever, because the estimated payout time is 12 years. It was calculated that the net present value is a negative 2.8 million--by discounting the annual cash flow over a 10-year period at a 5 percent interest rate. Thus, the manufacture of only the crude abrasives cannot be recommended.

It was found, however, that the conversion of crude grain to finished grit offers an attractive commercial venture. In this case a total investment of \$7.232 million can be recovered in 4.3 years with an average sales price of \$318 per ton. The net present value over a 10-year period, discounted at a 10 percent interest rate, is a positive \$3.37 million.

Special grades of the finished grit must be emphasized for manufacturing synthetic abrasives in any domestic facility. If an average sales price of \$418 per ton can be realized for the special grades of grit, a payout time of only 3.6 years is needed to recover the total investment of \$14.314 million. This is significantly lower than the 6.6 years calculated for an average sales price of \$318 per ton.

A total of 134 employees will be required for the crude and grit silicon carbide operations. An additional 180 employees will be needed for the crude and grit

forms of fused aluminum oxide. The manufacture of only the two crude abrasives will require 157 employees and an equal number of employees for conversion of the crude to finished grit. Thus, a total plant staff of 314 is estimated.

The combined crude and grit facilities will require an investment of \$14.314 million, of which \$10.314 is fixed capital and \$4.000 million is working capital. Before this total investment can be made, however, it is imperative to define the specific segment of the crude and/or grit areas of the abrasives industry that can be served by a new plant at Reesedale.

It is suggested that only one electric furnace for each of the non-metallic abrasives be installed initially to be operated as a semi-commercial unit. The output of this unit will suffice for customers in the Pittsburgh area. This will also allow the operating group to develop the necessary process know-how required for establishing a firm market position outside the Pittsburgh area. After the plant has demonstrated its ability to meet the specifications for high quality forms of finished abrasive grit, the plant can be expanded for either crude and/or grit operations.

It is believed that this sequence is the only

approach that can be taken to build the proposed synthetic abrasives plant for finished grit that includes manufacturing the crude abrasive grain.

SINGMASTER & BREYER

D. R. Whitlock
D. R. Whitlock

D. L. Stockton
D. L. Stockton

April 26, 1965

II. PROJECT DESCRIPTION

A. SILICON CARBIDE

1. General (See Flow Sheet page II-1a)

Crystals of silicon carbide (SiC) are formed by the high temperature reaction at $2000^{\circ}\text{C}.$ - $2400^{\circ}\text{C}.$ between silica sand (SiO_2) and carbon in an electric furnace of the horizontal resistance type. This procedure is essentially that followed by Acheson in 1891 when he discovered silicon carbide. The high purity sand with at least 99.0 percent SiO_2 content is mixed with green petroleum coke, sawdust and salt to form the furnace feed mixture. Sawdust is added to obtain a porous mix so that the carbon monoxide generated can escape during the reaction. Salt is added to permit removal of the bulk of metallic impurities in the form of volatile chlorides from the high temperature reaction zone where pure silicon carbide is formed. The impurities that remain in the crystal lattice of the silicon carbide are evident by the color of the silicon carbide crystals produced. It is necessary to treat chemically the silicon carbide grain (crude abrasive) in order to remove extraneous surface contaminants prior to final classification of the abrasive into finished grit. Size reduction and classification of the crude abrasive into a multiplicity of finished grain, flour, and

powder particle sizes requires a complex beneficiation circuit.

The proposed plant has a nominal annual capacity of 12,500 tons of silicon carbide abrasive when operating 21 shifts per week. For a schedule other than a 3-shift, 7-day week the capacity is:

<u>Shift/ Week</u>	<u>Shift Schedule</u>	<u>Nominal Capacity</u>	<u>Design Capacity</u>
21	3-shift x 7-days	12,500 tpy	100%
15	3-shift x 5-days	7,500 tpy	60%
10	2-shift x 5-days	5,000 tpy	40%
5	1-shift x 5-days	2,500 tpy	20%

A total of nine x 5000-KW electric furnaces will be installed but only three will be drawing power at any time. The sequence of the operating cycle requires the other six to be cooling, unloading, reassembling, and recharging. The estimated weekly output is 250 tons of crude silicon carbide from a total of 12.5 batches at 20 tons SiC each.

2. Plant Layout

The silicon carbide process area will consist of feed preparation, the electric furnace operation, separation and chemical treatment of the crude abrasive, and finishing operations for the silicon carbide grain and powder into the various grit sizes. In addition, the usual site facilities for offices, laboratories, locker rooms, shop, boiler house and warehouse are included. A plot

plan of the proposed buildings is shown on page II-3a for a synthetic abrasives plant at the Reesedale Site (Armstrong County in Pennsylvania). The reference ground level for the site is at an elevation of 850 feet in order to accommodate a siding from the Pittsburgh and Shamut Railroad and an access to the existing county highway.

3. Feed Preparation

Unloading stations for both covered-hopper railroad cars and trucks are provided to receive incoming raw materials. A combination of belt conveyors and bucket elevator will take the raw materials from the unloading stations to the line of primary storage bins for sand, petroleum coke, salt and sawdust. A storage capacity of at least 2-3 months reserve is planned. Each 30-foot diameter bin will contain a suitable breaker device to avoid "dead" storage and to maintain a free-flowing discharge. Provision has been made to crush the incoming green petroleum coke, to hold it for size reduction, and to transfer it to its respective bin for coarse (8x16 mesh), medium (16x65 mesh), and fines (minus 65 mesh).

Each of the basic raw materials will be either purchased or treated to obtain the desired particle size distribution of the feed mixture--at least 50 percent in the 16x65 mesh range, which is equivalent to that of the

silica sand. It is planned to use ratio-controlled gravimetric feeders to withdraw the desired amounts of raw materials from central storage bins prior to collection on a central feed belt conveyor.

A weigh car will be used to check the total weight of each fresh feed mix and to serve also as a blender. Each batch of fresh feed mix should be prepared as needed to charge a furnace to avoid segregation. A homogeneous mix is needed in the furnace to assure uniform porosity of the charge as well as chemical composition. A mobile charge truck will reduce dust generation normally associated with belt conveyor transfer points. Also, it can be discharged by an air-slide from the mezzanine above the furnace area. Freight elevators have been included in the process buildings to permit materials handling by mobile units.

4. Furnace Arrangement

It is planned to install the nine x 5000-KW furnaces in order to reduce the unit cost. Three single-phase 5000-KW transformers will service three of the furnaces. Each furnace unit will have overall inside dimensions of 60 feet long x 10 feet wide x 10 feet high, and will hold a total charge of 200,000 pounds. The nine furnaces will be installed side by side to permit easy access during servicing, charging, and unloading.

The horizontal furnaces are constructed with fixed heads (48 inches thick) to accommodate the water-cooled, 15-inch diameter carbon electrodes. The removable reinforced concrete side sections with overall dimensions of 10 feet high x 6 feet wide x 15 inches thick will permit harvesting of the reaction mixture. A steel framework is used to support the concrete and brick lined sections of the heads, bottom and side sections. An empty furnace will resemble a U-shaped trough into which the charge can be added from either mobile feed cars or hoppers transported to the furnaces by an overhead traveling crane. Adequate working space will be provided around each furnace with 10-foot wide truck aisles along each bank for easy access during dismantling, discharge of the reaction mixture, reassembly, and reloading.

The electric power supply will be installed according to standard safety features. A control room will be adjacent to the electric power receiving area with main switchgear and step-down transformers. A total of 10,000 kilowatts will be the design load on a full-time basis. Only alternating current is needed for the furnaces. A bed of granular graphite is placed along the center of the charge at the elevation of the electrodes to attain the high temperature required.

5. High Temperature Reaction

An empty furnace will be filled to the level of the electrodes with fresh mix by use of either a 5-10 ton car or crane hoppers designed to place feed mixture along the length of the furnace. The material will be discharged by gravity and conveyed by an air-slide from the hopper bottoms of the feed containers. It will be necessary, however, to add, also, some recycle mix, which consists of unreacted material and partially converted material ("Firesand") that has been recovered from previous batches. For an estimated conversion of about 60 percent of the silica sand (contained in 120,000 pounds of feed mixture) only 25 weight percent of the original furnace charge is recovered from the ingot as suitable crude abrasive silicon carbide. As a result, the ratio of the recycle mix to the fresh mix is about 2:3 and constitutes a significant materials handling problem in the process.

A layer of granular graphite is placed between the two furnace heads at the level of the electrodes for a depth of 6-10 inches and a width of about 6 feet. The purpose of the graphite layer is to serve as a conductor of electric current during the heating up of the batch to reaction temperature. Also, it allows adequate control of the temperature profile along the furnace during the re-

action period. The voltage is regulated to maintain a temperature of 2000°C-2400°C in the central portion of the furnace. The end effects and the heat losses along the sides and top of the furnace are followed by several longitudinal traveling thermocouples to permit progress of the reaction to be followed and to avoid overheating of the mix. The voltage applied at the beginning of the run is 400 volts and then is reduced to 200 volts at the end of the run. Care is required to avoid decomposition of the silicon carbide, which begins at 2500°C.

The upper section of the furnace is filled with the proper ratio of fresh and recycle mix after the graphite core is added. The top of the charge is mounded above the top of the furnace because there is significant shrinkage of the charge during the reaction. About 60 weight percent of the reaction zone is volatilized as carbon monoxide. The release of carbon monoxide is evident as it burns along the surface of the charge and at openings in the furnace walls.

6. Discharging of Furnace

The formation of silicon carbide requires a reaction time of about 36 hours at a temperature of 2000-2200°C. It is necessary to allow 60-72 hours, however, for cooling and unloading of the furnace charge. When the

reaction period is finished the insulated side sections are removed by use of the overhead crane and adequate cooling is allowed before the reacted mass is harvested. The loose mix and firesand can be transported by mobile, front-end loaders to a feed chute into a bin below the main working level. A grizzly will be provided at the chute to prevent lumps from blocking the crushing unit ahead of the bucket elevator that returns the recycle material to the main "old-mix" storage bin. Mobile vacuum cleaners and pneumatic conveying units will also be used in discharging the loose material that surrounds the ingot (large interlocked crystals of silicon carbide) of the furnace.

The silicon carbide crystals are grown by vaporization and condensation, with a minimum of decomposition, so that a massive oval ingot is formed along the furnace axis. This ingot has a crust of volatile compounds formed by the impurities that have condensed in a layer 1-2 inches thick. The ingot interior is a core of graphite that must be recovered and recycled to process.

The ingot mass is broken down into lumps so that the lumps of crude abrasive crystals can be separated easily. The crust of firesand will be sorted and discarded to a stockpile in the yard, if necessary, to remove impurities or to be sold as off-grade crude grain.

7. Crude Abrasive and Finished Grit

The crude silicon carbide crystal lumps are collected in bulk for weighing and interim storage before transfer to the process area. The material is first sent to a jaw crusher for reducing the crystals to minus 3/4-inch size and then to a suitable mill for grinding to about 1/4-inch size, each followed by screening steps. Recovery and storage of crude abrasive can be done at this point if desired for shipment to customers.

Some of the material is sent to a roll crusher for reduction to about 20-mesh size. A screening operation is performed at this point to separate additional grain and then the oversize is sent to a ball mill for grinding to the finer sizes. The wet grinding operation is followed by a magnetic separator to remove iron and other magnetic impurities. The silicon carbide is sent to complex sizing operations that include cycloning and sedimentation. Suitable thickeners are provided for chemical treatment and washing the silicon carbide in order to remove the colloidal material and any surface impurities.

The multiplicity of grit particle sizes of silicon carbide grain and powder requires suitable storage for the fractions recovered by the primary wet classification methods. Final classification is performed in Pyrex

columns using both elutriation and sedimentation to fractionate material below 200-mesh size (74 microns). These grinding and classification steps require careful control of the operation in order to meet the specifications. In addition, some customers will have unusual demands in regard to the friability of the materials, as well as particle size and color.

The settled silicon carbide powder fractions are transferred to stainless steel trays for drying. The batch dryer will accommodate several racks of trays to permit batch identification and the particle size. The trays will be unloaded and any lumps disintegrated before the material is weighed and transferred to the main cluster bin for storage of finished material. The various particle sizes will be discharged from the cluster bin for blending and final weighing before sampling and packaging into drums. The drums will be identified and held in storage for the trade.

Production of unclassified silicon carbide flour is accomplished by feeding the final slurry to a corrosion-resistant vertical dryer. The dried material will be disintegrated and then screened to isolate the desired fraction of given particle size distribution.

The finishing operations require complete flexi-

bility in processing to handle 1/4-inch to 20-mesh coarse crystal fractions (grain), and the multiplicity of grit sizes of various silicon carbide grades (e.g. black, green, etc.).

8. Ventilation Requirements

In the feed preparation area the main storage bins and coke crushing operations will be housed to protect them against the weather. Also, adequate dry dust collection facilities will be installed to maintain acceptable working conditions in this area. The carbon dust and other fines that are collected will be recycled to the fresh mix makeup stream.

The furnace room will require adequate ventilation to remove the heat gained from the furnaces and to maintain a clean working area. During the loading and unloading operations specific ventilation will be provided by mobile vacuum cleaners and pneumatic pickup units to avoid accumulation of dust in the furnace room. During the reaction any evolution of volatiles and carbon monoxide will be removed by adequate air changes.

9. Process Control

Adequate monitoring units of the process streams and furnace operations will be installed to follow the performance of the equipment. A television camera will be

placed to scan the bin discharge streams. Pilot lights and alarms will warn against drastic changes in flow rates and conditions.

Emphasis will be placed upon the purchase of the latest laboratory equipment to perform rapid and reliable analytical work to expedite process control as well as quality control of the finished grit. Direct readout vacuum emission spectrometers and x-ray fluorescence machines not only reduce the lag time from hours to minutes, but also reduce the unit cost for laboratory work. A thermogravimetric balance and an electron microscope are also considered imperative to maintain and to improve the process.

B. FUSED ALUMINUM OXIDE

1. General (See Flow Sheet page II-12a)

Fused aluminum oxide abrasive is prepared by reacting calcined bauxite with green petroleum coke and carbon steel turnings in a submerged-arc electric furnace at a temperature of 2000°-2200°C. The carbon reduces most of the metallic and non-metallic oxides except the aluminum oxide. As a result, an alloy phase of crude ferrosilicon metal sinks to the bottom of the furnace. Additional feed is added as the fused alumina melt is accumulated and the electrodes are maintained just above the surface of the

fused alumina. Large batch furnaces that produce fused alumina ingots from 20-40 tons in weight have been developed along the lines of the original units. During the last 10-15 years, however, a successful effort has been made to use a tilting electric furnace from which the upper layer of fused alumina can be poured into molds and the lower layer of crude ferrosilicon can be withdrawn periodically.

The chemical composition of the fused alumina can be controlled by the grade of the starting raw materials. The amount of iron added is carefully controlled to give a crude ferrosilicon with no more than 14-15 percent silicon content. Impurities such as titanium are desirable for the regular fused alumina because the toughness of the product is increased. For white fused alumina, however, it is necessary to start with pure aluminum oxide suitable for reduction to aluminum metal. During the last 10 years special grades of fused alumina have been prepared by the addition of materials such as zirconium oxide in order to achieve improved performance of the abrasive.

The annual production of fused aluminum oxide is much greater than that for silicon carbide. The availability of low cost calcined bauxite and pure alumina has permitted crude abrasive fused alumina to be produced at a

cost of about \$100 per ton or five cents per pound. As in the case of silicon carbide, about 80 percent of the crude abrasive is manufactured in Canada and shipped to finishing facilities of the United States. The treatment steps of size reduction, chemical treatment, wet classification, drying, and final sizing operations are carried out in a manner similar to that employed for silicon carbide grit. The finished grain, flour, and powder of fused alumina grit is carefully controlled as to grade, particle size, hardness, specific surface and other properties depending upon the requirements of the customer.

The proposed plant has a nominal capacity of 25,000 tons per year of fused aluminum oxide. Electrical power will be supplied by three main transformers, each with a capacity of 2500 kilowatts. An adequate number of furnace cars will be used to permit the charging, high temperature fusion, controlled cooling (crystallization), and final unloading of the ingot. The button of crude ferrosilicon alloy will be separated and sent to a stockpile. Both crude abrasive grain and finished grit will be produced by this plant.

2. Plant Layout

The process area will consist of storage for incoming raw materials, feed preparation, a furnace room,

separation and chemical treatment of the crude abrasive, and the necessary finishing operations for fused alumina grit in the various grain and powder sizes. The fused alumina section will be located on the site so that there is a minimum chance for contamination of this high purity material by any dust from the silicon carbide operation. As shown in a proposed plot plan of the Reesedale Site (see page II-3a), the fused alumina unit would share with the silicon carbide operation the usual site facilities for an administration building, warehouse, shop, and boiler house.

3. Feed Preparation

The calcined bauxite (abrasive grade--86% Al_2O_3) will be received in covered, hopper-bottom freight cars. It will be transported from the rail car unloading station to storage bins by pneumatic conveyor. Green petroleum coke of the desired particle size (16-mesh x down) will be moved from the silicon carbide feed preparation area and then transferred by pneumatic conveyor to storage. A suitable dust collection system will be provided for the pneumatic conveyor exhaust and vents from the storage bins.

It is planned to haul scrap steel turnings from the Pittsburgh Area, or closer, as the source of the iron that is needed for combination with silicon in the bauxite

feed. A truck unloading ramp will be provided so that the steel turnings can be dumped directly into a bin.

A suitable weigh car for blending the feed mix will be mounted on a track below the storage bins. Gravimetric feeders will be used at each bin discharge point. A charge of ten tons will be prepared and the mobile weigh car moved to load an empty furnace unit to a depth of about three feet. Another charge will be prepared and dumped into a bin to add feed material as required during the actual fusion step. A total of 20-30 tons of feed mixture will be required for each ingot of fused aluminum oxide.

The chemical composition of each of the raw materials must be determined and the overall composition of the feed mixture must be carefully controlled to obtain the desired grade of fused alumina. The friability of the finished product depends upon the titanium dioxide content of the fused alumina. In addition, the thermal history of the batch affects the porosity and texture of the alumina crystals. Care must be taken to avoid an excess of alkaline material, for example, calcium, magnesium and sodium oxides. The content of silica must be determined in order to adjust the ratio of iron to silicon in the ferrosilicon by product. The amount of carbon added to the batch must be controlled in order to avoid over-reduction of the metallic oxides so

that none of the aluminum oxide is converted to aluminum carbide (Al_4C_3). The latter will decompose upon contact with moisture in the air and destroy the abrasive characteristics of the entire ingot.

4. Furnace Operation

For purposes of this preliminary estimate the simple block type of submerged arc furnace has been adopted. These units will yield an ingot up to eight feet in diameter and six feet high weighing 20-30 tons. The submerged arc furnace will be constructed so that it is mobile and will travel on a track inside the furnace room to carry out the necessary sequence of operations.

Each batch will be fused at one of three stations with a power input of 2500-KW each. Each furnace will have three prebaked electrodes mounted on a suitable assembly whose elevation can be controlled by a hydraulic lifting device. The power supply to the electrode assembly will be automatically controlled as near as possible to a constant value. It is necessary to control the position of the electrode assembly automatically in order to maintain the desired flow of current. Each furnace will be constructed with a steel framework mounted on a suitable carriage. Two layers of firebrick will be used for thermal insulation and then a layer of graphite blocks will be add-

ed for chemical resistance to the molten charge. The slope of the graphite blocks will permit the heavy layer of crude ferrosilicon metal to accumulate at the center of the furnace. A cylindrical steel shell will serve as the side of the furnace and will be constructed so that it can be placed in position over the permanent bottom lining of the furnace. The heavy steel plate will be jacketed on the outside to maintain the interior surface of the steel at a temperature far below the melting point of the alumina. As a result, a thick crust of alumina accumulates on the interior of the shell and serves both as a thermal insulator and maintains purity of the batch.

Following the fusion period, which can require up to 24-30 hours depending upon the amount of material added, the electrode assembly is raised and the furnace unit is moved to the crystallization area. Careful control of the time and temperature of the melt is imperative in order to obtain the desired crystal size of the crude abrasive. It is felt that the jacketed shells permit better control of the crystallization cycle.

5. Crude Abrasive Grain

After the required cooling cycle has been completed the furnace unit is disassembled and the massive ingot is unloaded. The button of crude ferrosilicon is

separated at this point along with any impurities that are evident on the surface of the ingot. Also, any non-fused material of feed alumina is recovered and recycled to process.

The ingot is fractured by use of a 1-2 ton manganese steel ball that is dropped from an electro-magnet. This operation is repeated until chunks or lumps of the alumina crystals can be fed through a three-inch grizzly to a jaw crusher.

The crude abrasive is screened so that only the plus 3/4-inch material is sent to a jaw crusher. The minus 3/4-inch crude abrasive grain is collected in pallet boxes so that it can be weighed and sampled and held in storage. From this point it is sent to the preparation of fused alumina grit or shipped as crude abrasive grain to customers.

6. Fused Alumina Grit Finishing

The crude abrasive grain is processed by a suitably sized reduction operation, followed by wet and dry classification in order to obtain the necessary amounts of finished grain and grit materials. In general, the operations parallel those carried out for fractionation of the silicon carbide and need not be repeated. (See Section II. A, 7).

There is a demand, however, for the finer sizes (powder) of fused alumina grit so that extensive sedimentation and classification must be carried out for the sub 10-micron particles. These fused alumina powders are employed for precision lapping and polishing of high strength steels and other hard, heat-sensitive, materials.

7. Ventilation Requirements

It is considered good practice to provide adequate general ventilation in all of the processing buildings as discussed on silicon carbide. Also, specific ventilation will be provided to pick up dust from process points in order to avoid contamination of the working area and to prevent exposure of the operating personnel to the particulate abrasive matter.

Every effort must be made to avoid sub-micron particles from being inhaled by not only ventilation but also by wearing a dust mask. Regular x-rays of the workers is recommended to observe any unusual conditions that might have developed during a 6-month period.

8. Process Control

The latest instruments will be installed to permit rapid and reliable process and quality control. The x-ray fluorescence machines might also be placed in the plant process area to allow direct readings by the operator

of the chemical composition at a given process point.

A machine to determine the specific surface of the alumina is critical for the preparation of flour and powder grit products. Other physical tests will include, melting point, specific gravity of fused alumina, bulk density of grit products, hardness of fused alumina, and particle size distribution. For particles below 200-mesh (74 microns), it is necessary to use laboratory elutriation and sedimentation methods, microscopic examination, and specific surface measurements.

III. CAPITAL COST ESTIMATE

It is estimated that the synthetic abrasives plant will require a total fixed capital expenditure of about 10.3 million dollars. This includes complete process facilities for the manufacture of silicon carbide and fused alumina in both the crude abrasive and finished grit forms. The site facilities (see page II-3a) will also include a suitable administration building, a warehouse and shop building, and a boiler house. Decentralized laboratory space, locker rooms, and lunch areas, have been planned for this preliminary estimate.

The proposed plant will require an area of about 2400 feet long by 1200 feet wide. The reference elevation of the plant would be about 850 feet, which is identical with the Pittsburgh and Shawmut Railroad that serves the Reesedale Site (see page I-1a).

1. Site Preparation

Clearing and Grubbing	\$ 25,000
Excavation, Grading &)	
Purchased Fill)	500,000
Railroad Spurs	79,000
Fence	30,000
Roads & Parking Areas	72,000
Pipe Racks	<u>50,000</u>
Subtotal	\$756,000

2. Utilities

Main Electrical Switchgear, Distribution & 480 V Substation	\$ 150,000
Water Treatment (Sanitary, Process, Cooling) with Distribution	100,000
Fire Water plus Storage	100,000
Chilled Water for Air Conditioning	50,000
Air (Process and Instrument)	25,000
Natural Gas	25,000
Fuel Oil Storage & Supply	25,000
Steam Distribution	50,000
Sewers (Sanitary with Treatment)	75,000
Industrial Waste Treatment	75,000
Tailings Area for Stockpile	<u>25,000</u>
Subtotal	\$ 700,000

3. Site Facilities

Security Office, Dispensary, Garage, & Truck Scales	\$ 100,000
Administration & Office Building	165,000
Boiler House and Other Utilities e.g. Air Conditioning	250,000
Warehouse & Shop Bldg. (150'x200')	255,000
Office Equipment (Desks, etc.)	50,000
Laboratory Apparatus	100,000
Spare Parts for Process	<u>50,000</u>
Subtotal	\$ 970,000

4. Process Buildings

Silicon Carbide:

Feed Preparation (100'x400'x60')	\$ 250,000
Furnace Room (150'x400'x50')	360,000
Finished Grit (200'x400'x50')	480,000
Lunch & Locker Room Facilities	25,000
Analytical Laboratory Facilities	<u>50,000</u>
Subtotal	\$1,165,000

4. Process Buildings (Continued)

Fused Aluminum Oxide:

Feed Preparation	(50'x200'x60')	\$ 100,000
Furnace Room	(200'x400'x50')	400,000
Finished Grit	(200'x400'x50')	480,000
Lunch & Locker Room Facilities		25,000
Analytical Laboratory Facilities		<u>50,000</u>
Subtotal		\$ 1,055,000

5. Process Equipment

a) Silicon Carbide (see page II-1a)

1) Feed Preparation	\$ 534,000
2) Furnace Operation	593,000
3) Treatment of Crude and Grit Finishing	<u>569,000</u>
Subtotal	\$ 1,696,000

b) Fused Aluminum Oxide (see page II-12a)

1) Furnace Operation	\$ 855,000
2) Grit Finishing	<u>749,000</u>
Subtotal	\$ 1,604,000

6. Breakdown of Plant Investment

Site Preparation	\$ 756,000
Site Development	700,000
Site Facilities	<u>970,000</u>

Subtotal \$ 2,426,000

Process Buildings

Silicon Carbide	\$ 1,165,000
Fused Aluminum Oxide	<u>1,055,000</u>

Subtotal \$ 2,220,000

Process Equipment

Silicon Carbide	\$ 1,696,000
Fused Aluminum Oxide	<u>1,604,000</u>

Subtotal \$ 3,300,000

TOTAL PLANT COST \$ 7,946,000

Engineering, Purchasing,
Construction Supervision
(13% of plant cost) 1,033,000

Contractor's Fee (5% of
plant cost) 397,000

ESTIMATED TOTAL COST \$ 9,376,000

Contingencies (10%) 938,000

TOTAL FIXED INVESTMENT \$10,314,000

IV. OPERATING COST ESTIMATE

A. DESCRIPTION OF COST ELEMENTS INVOLVED

1. Introduction

The unit operating costs for both silicon carbide and fused aluminum oxide as crude abrasive grain, now imported duty-free from Canada, and, also, finished grit have been estimated. It is necessary to assume that the plant will be able to supply either form of the regular crude and finished grit of these two synthetic abrasives. Also, if desired, high purity and special grades of each grit form could be made in the facilities.

In line with the current plant capacity and annual output of the combined Canadian and United States facilities, a new unit with about 10 percent of the respective abrasive capacity for the Reesedale Site was selected for the reference design. There has been considerable activity to install new crude abrasive grain manufacturing facilities at home and abroad. Also, the major firms in the field have installed new units for finishing of the crude grain into abrasive grit sizes. In addition, there has been emphasis upon improved quality of the bonded and coated commercial items used by the metal-working and other industries. As a result, the merging of smaller firms into the major companies (e.g. Carborundum and Norton)

has been evident in order to satisfy the demands imposed by new and complex grinding and polishing machinery.

The Reesedale Site is suitable for a synthetic abrasives plant because interruptible power is available "across the fence", the site is acceptable and with adequate area for expansion, basic raw materials are available locally, similar non-metallic industries are established in the area, and convenient transport of crude and finished goods is made possible by its geographical location. The consumption of abrasives is dominant in the industrial northeast quadrant of the United States. Also, Reesedale is in a position to save one or two days in delivery of an order within a radius of less than 500 miles.

2. Cost Elements Included

a) Basic Raw Materials

The factor for each basic and auxiliary chemical material is established by the calculated physical requirement per unit of product. The delivered price of each chemical is multiplied by the material factor to determine its contribution to the unit cost of the crude or finished abrasive.

For example, 1.65 tons of high purity silica sand is needed per ton of crude silicon carbide produced. At a delivered price of \$7.77 per ton of sand, the unit cost is

\$12.70 per ton of crude abrasive.

b) Utilities

Electrical power is the major utility item because electric furnace operations are needed to synthesize the abrasive products. The power rate in mills per kilowatt-hour is critical because it determines the contribution of the power cost element to the total unit manufacturing cost. For example, to prepare one ton of crude silicon carbide requires about 7000 KWH, which will result in a unit cost of \$35 per ton of abrasive at 5 mills per KWH. The estimated market value of crude silicon carbide is \$150 per ton so that the unit cost for power is 23.5 percent of the total. As a result, crude silicon carbide has always been manufactured in an area with a low power rate. Canada has maintained its dominant position as the source of crude abrasives because power has always been available at a rate of 4 mills per KWH.

Other utilities include all types of water, natural gas, steam, and air. The usual facilities for drinking water, boiler feed water, cooling water, and fire water are provided. This includes treatment of fresh water and any recycle water streams as well as storage tanks. Air conditioning of office, cafeteria and laboratory space is accomplished by a central system circulating hot water in

the winter and chilled water in the summer months.

Natural gas with fuel oil as a standby is assumed for the boiler. Low pressure steam cannot be purchased from the West Penn Power Company to avoid on-site steam generation.

Plant air will be supplied by a centrifugal compressor. An adequate supply of dehydrated and oil-free instrument air will be accumulated and distributed to the pneumatically-operated, process control points. Secondary treatment of the instrument air might be necessary on a decentralized basis to insure good performance.

c) Other Materials

This will include all maintenance and repair items along with office and laboratory supplies, safety equipment, freight, telephone and telegraph charges, janitor supplies and miscellaneous items. The maintenance materials can be assumed equal to the maintenance labor.

All other supplies are assumed equal to one-half the charges for all labor exclusive of direct operating and maintenance labor.

Another item added under other materials is the unit cost of the liners and drums used in packaging the finished products.

d) Plant Organization and Labor Rates

An adequate work force has been included with labor rates above the regional and local averages to insure efficient operation. This will permit the highest quality abrasives to be made at the lowest possible cost and, as a result, to penetrate the competitive abrasive marketing area. Process control will be emphasized by training the supervisors and operating crews over an adequate period before plant start-up. In addition, the use of the latest laboratory machines for analyzing all raw materials, feed batches, process samples, and finished goods is planned. This reduces not only the control laboratory staff but also, provides rapid and reliable information to the technical staff—essentially no delay in reporting the data to the operating crew. Sample preparation will require careful control to obtain a representative sample that is subdivided in order to apply x-ray fluorescence and other more sophisticated techniques for analysis.

PLANT STAFF

<u>Administration</u>		<u>Annual Rate</u>	<u>Annual Payroll</u>
1 - Plant Manager	@	\$20,000	\$20,000
1 - Plant Superintendent	@	16,000	16,000
1 - Tech. Superintendent	@	16,000	16,000
2 - Department Heads	@	12,000	24,000
<u>2</u> - Secretaries	@	5,000	<u>10,000</u>
7			\$86,000

Industrial Relations

1 - Personnel Manager	@	10,000	10,000
1 - Captain	@	7,500	7,500
4 - Guards	@	5,000	20,000
1 - Doctor & Nurse	@	10,000	10,000
1 - Safety Inspector	@	6,500	6,500
<u>2</u> - Janitors	@	4,000	<u>8,000</u>
10			62,000

Office

1 - Office Manager	@	13,000	13,000
1 - Secretary	@	5,000	5,000
1 - Plant Accountant	@	10,000	10,000
2 - Accounting Clerks	@	4,200	8,400
1 - Typist	@	3,600	3,600
1 - Purchasing Agent	@	10,000	10,000
1 - Purchasing Clerk	@	4,200	4,200
2 - Purchasing Typists	@	3,600	7,200
1 - Warehouse Foreman	@	7,200	7,200
2 - Warehouse Clerks	@	4,200	8,400
<u>1</u> - Yard Foreman	@	7,200	<u>7,200</u>
14			84,200

Laboratory

1 - Plant Chemist	@	10,000	10,000
1 - Clerk	@	4,200	4,200
2 - Analytical Chemists	@	8,400	16,800
8 - Lab Technicians	@	4,800	38,400
<u>8</u> - Samplers	@	4,200	<u>33,600</u>
20			\$103,000

PLANT STAFF (Continued)

<u>Operations Department</u>		<u>Annual Rate</u>	<u>Annual Payroll</u>
4 - Shift Foremen SiC	@	\$ 8,400	\$ 33,600
4 - Shift Foremen FAO	@	8,400	33,600
2 - Clerks	@	4,200	8,400
<u>1</u> - Receptionist	@	3,600	<u>3,600</u>
11			79,200

Shift Operators

40 - Crude Silicon Carbide	@	5,200	208,000
<u>40</u> - Silicon Carbide Grit	@	4,850	<u>194,000</u>
80			402,000
40 - Crude Fused Alumina	@	4,650	186,000
<u>40</u> - Finished Alumina Grit	@	4,850	<u>194,000</u>
80			380,000

Maintenance Department

1 - Plant Engineer	@	12,000	12,000
2 - Clerks	@	4,000	8,000
4 - Maintenance Foremen	@	7,500	30,000
8 - Lead Men	@	6,600	52,800
16 - Mechanics Crude SiC	@	6,000	96,000
9 - Mechanics SiC Grit	@	6,000	54,000
16 - Mechanics Crude FAO	@	6,000	96,000
9 - Mechanics Grit FAO	@	6,000	54,000
1 - Draftsman	@	5,000	5,000
2 - Machinists	@	6,600	13,200
<u>4</u> - Boiler House Operators	@	5,000	<u>20,000</u>
72			441,000

Bull Gang

4 - Truck Drivers	@	5,000	20,000
6 - Yard Men	@	4,000	24,000
4 - Mechanical Helpers	@	4,500	18,000
<u>6</u> - Operator Helpers	@	4,500	<u>27,000</u>
20			89,000

<u>314</u> Total Employees	@	\$5,500	<u>\$1,726,400</u>
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e) Payroll Burden

A charge of 25% of all direct labor is applied to cover social security, hospitalization, group insurance, major medical insurance, vacation pay, overtime pay, and other fringe benefits.

f) Depreciation

A nominal rate based on a useful life of 10 years has been assumed to follow the average applied in the chemical and metals industries. The government allows only specified depreciation rates on each type of fixed capital. In this study, however, a 10 percent factor has been applied to the total capital expenditure of plant investment plus working capital to provide adequate funds to return the capital authorized only when necessary.

g) Working Capital

The working capital will be 10 percent of annual sales plus 20 percent of the plant-level operating cost to cover inventories of raw materials, in-process material, and finished goods. The abrasives industry is abnormal in that a multiplicity of at least 50 grit sizes must be maintained in inventory for each of silicon carbide and fused alumina types. Thus, working capital is higher than might be expected.

h) Direct Plant Expense

This is local and state taxes applied directly at the plant level along with insurance and other items. It is assumed that 1.5% of the total plant investment will cover this item, which is 65 mills on land and buildings assessed at 40 percent fair market value.

i) Indirect Plant Expense or Overhead

This includes process research and development, technical service, sales expense, product distribution costs, and general home office allocated expense. In general, this is 5-10 percent of annual sales for chemical and related industries. In this case, a value of 5 percent will be applied for the crude grain and 10 percent for the finished grit. The latter will require more research and development activities to assist the technical service demanded to maintain a competitive market position. Special grades of fused alumina include an addition of 10 percent zirconium oxide to the melt to obtain an improved abrasive.

B. SILICON CARBIDE

1. Crude Abrasive Grain

a) Raw Materials

1) High Purity Silica Sand

One primary source of silica for manufacturing silicon carbide is near Mapleton in the southwest corner of Pennsylvania. During the last two years the Pennsylvania Glass Sand Corporation has made available a Keystone S-C Special sand (Size 5Q-ROK) for silicon carbide manufacture. It is withdrawn from the sand plant processing circuit with a 5 percent moisture content (maximum) and loaded into hopper-bottom cars. Closed rail equipment is used normally but open equipment can be utilized when contamination can be avoided.

A chemical analysis of the high purity silica sand is:

SiO ₂ (99.0% Min.)	99.6% Typical
Fe ₂ O ₃	0.04 - 0.06%
Al ₂ O ₃	0.02 - 0.18%
TiO ₂	0.15% typical
CaO	0.01% typical
MgO	Trace
Loss on Ignition	0.8%
Free Water	4 - 6%
In damp material	

The particle size distribution of the silica sand is a nominal 20 x 40 mesh fraction:

<u>Screen Size</u>	<u>% Retained</u>	<u>% Cumulative</u>
16-Mesh	1-14	1-14
20-Mesh	11-40	12-54
30-Mesh	52-35	64-89
40-Mesh	25-9	89-98
50-Mesh	9-2	98-100
Pan	2-0	100-100

The purchase price of the special damp Keystone sand is \$2.25 per ton in comparison with \$3.75 per ton for the regular dry Keystone size 5Q-ROK. One advantage of an abrasives plant at Reesedale is shown by the table of prices for delivered sand:

<u>Size 5Q-ROK</u>	<u>PLANT LOCATION</u>		
	<u>Reesedale</u>	<u>Niagara Falls</u>	<u>Quebec</u>
Purchase Price \$/T	3.75	3.75	3.75
Freight Cost, \$/T	<u>4.02</u>	<u>4.99</u>	<u>8.33</u>
Delivered Price, \$/T (closed equipment)	7.77	8.74	12.08
<u>Keystone S-C Special</u> (5% Free Moisture)			
Purchase Price, \$/T	2.25	2.25	2.25
Delivered Price, \$/T (Closed equipment, 40-ton minimum)	6.27	7.24	10.58
Delivered Price, \$/T (Open equipment, 40- ton minimum)	5.62	6.59	9.93

2) Green Petroleum Coke

A high quality petroleum coke is required to maintain the quality of the finished silicon carbide. It is available from the Great Lakes area and, also, Gulf Coast points. In general, the delivered price of petroleum coke will be in a range of \$18-\$22 per ton. The raw coke is shipped as minus 2-inch lumps. Some chemical analysis data are:

Fixed Carbon	90%
Volatiles	9-11%
Free Moisture	5-7%
Sulfur (2% S max.)	1.0-1.1%
Ash Content	0.25%
Iron (0.10% Fe max.)	0.02-0.04%
Silicon (0.10% Si max.)	0.02-0.04%

3) Sawdust

A local supply is guaranteed from the nine sawmills in Armstrong County. Fresh sawdust that is dry but with a high sap content can be purchased for less than one dollar per ton. A trailer can serve as the collector bin for 8-10 tons of material. Haulage costs were reported by West Penn Power's Industrial Development Group, to be about \$25 per load--for 8-10 tons--up to a distance of 25 miles. Thus, the delivered cost of sawdust will be \$3.50-\$4.00 per ton.

4) Carbon Electrodes

These will be purchased from one of the commer-

cial suppliers at a price of about 12 cents per pound. Freight will be about 3 cents per pound so that the delivered price is estimated at 15 cents per pound.

5) Granular Salt

A delivered price of \$10 per ton has been assigned for the 20 x 65 mesh salt desired. Only one 20-ton truck load is required annually.

b) Chemical Reaction

The conversion of silica to silicon carbide has a theoretical physical yield of 67 percent.

	<u>Silica</u> <u>Sand</u> SiO ₂	<u>Carbon</u> 3C	=	<u>Silicon</u> <u>Carbide</u> SiC	<u>Carbon</u> <u>Monoxide</u> 2CO
Molecular Weight	60	3x12		40	2x28
Theoretical Yield	1.50 lb.	0.90 lb.		1.00 lb.	1.40 lb.
Actual Yield	1.67 lb.	1.0 lb.		1.0 lb.	--

Note that at least 1.40 pound of carbon monoxide per pound of silicon carbide is generated. Care is taken to maintain the stoichiometric ratio of silica to carbon for the reaction at 2000°-2200°C.

c) Nominal Design Data

The necessary shipments of raw materials, the number of batches, and the direct labor (operators) to manufacture a total of 12,500 tons crude abrasive annually is given by Table A. These data allow negotiations for freight

TABLE A

CRUDE ABRASIVE SILICON CARBIDENominal Design Data

<u>Item</u>	<u>Factor (a)</u>	<u>Batch</u>	<u>Month</u>	<u>Year</u>
Silica Sand, Ton	1.65	33	1650	20,625
Green Petroleum Coke, Ton	1.00	20	1000	12,500
Sawdust, Ton	0.165	3.3	165	2062.5
Salt, Ton	0.001	0.02	1.00	12.5
Graphite ^(b) , Ton	0.20	4.0	200	2,500
Electrodes, Ton	0.005	0.10	5.0	62.5
Furnace Load, Ton	5.00	100	5000	62,500
Furnace Volume, Cu. Ft.	300	6000	--	--
Furnace Power ^(c) KWH	7000	140x10 ³	7x10 ⁶	87.5x10 ⁶
Total Batches	0.05	1.0	50	625
Silicon Carbide, Ton	1.00	20 ^(d)	1000	12,500
Direct Labor, Employees	40 with four shifts @ 10 men each			
Total Labor, Employees	67 out of 314 total at plant.			

(a) Units of item needed per ton silicon carbide

(b) Recycled material

(c) Two 5000 KW transformers needed for 8-10 furnaces
(each 100-Ton capacity)

(d) A furnace batch of 200,000# has about 120,000# reacted that gives 40,000# of silicon carbide crude grain.

charges and estimates for inventory charges assigned to raw materials, material-in-process, and finished goods.

d) Utilities

Preliminary design data for crude abrasive are:

Furnace Power	10,000 KW
Process Power	400 KW
Ventilation Power	250 KW
Site Power	500 KW
Refrigeration Power	500 KW
Air Compression Power	<u>25</u> KW
Total Connected Power	11,675 KW
Sanitary Water	25 gpm
Process Water	25 gpm
Cooling Water	200 gpm
Natural Gas	3,000 CFH
Steam	1,000 lb./hr.

For the nominal output of 2.0 tons per hour silicon carbide, the utilities, other than for the furnace reaction, are estimated as follows:

Auxiliary Power	50% load x 1675 KWH @ 5 mills	\$4.20
Plant Water	$\frac{50 \text{ gpm} \times 60 \times 20\text{¢}}{1000 \text{ gallons}}$	0.60
Cooling Water	$\frac{200 \text{ gpm} \times 60 \times 5\text{¢}}{1000 \text{ gallons}}$	0.60
Natural Gas	$\frac{3,000 \times 50\text{¢}}{1000}$	1.50
Steam	$\frac{1,000 \times 50\text{¢}}{1000}$	0.50
		<hr/>
Hourly Charges		\$7.40
Unit Cost Per Ton Crude		\$3.70

e) Other Materials

1) Maintenance Material

The estimated annual maintenance labor for crude silicon carbide is \$96,000. Thus, the maintenance material cost per ton crude abrasive is \$7.68, which is calculated from \$96,000 divided by 12,500 tons.

2) Miscellaneous Materials

The allocation of the direct plant expense is based on the relative sales value of the respective abrasive items. If the unit sales price for finished grit is assumed equal for the silicon carbide and fused alumina, then the ratio of the annual outputs will determine the ratio of expense distributed. Silicon carbide will carry one part of the expense and fused alumina two parts based on a ratio of 12,500 tons/25,000 tons.

The plant expense allocated to silicon carbide will be divided equally between the crude and finished abrasive forms, which is the ratio of the respective market values (\$150/\$300 sales price per ton).

For the fused alumina, however, the plant expense will be divided in a ratio of 1/2 for the crude and finished grain forms.

The total annual payroll for all labor exclusive of operating and maintenance labor is \$644,400. Silicon

carbide will be assigned \$214,000, which will be allocated in equal amounts of \$107,400 to the crude and grit forms.

The other materials will be \$4.73 per ton of silicon crude if 50 percent of the other labor is used in the manufacturing cost estimate.

3) Containers

A charge of \$5 per ton is used for the crude abrasive.

f) Miscellaneous Expense

1) Local Taxes

In Armstrong County the market value of the land and buildings is taxed at a rate of 65 mills (\$6.50 per \$100 assessed value). The fixed plant investment of \$10.3 million has about \$3.0 million for the assessed valuation. Silicon carbide will carry \$1.0 million of this \$3.0 million so that the annual local taxes will be \$65,000 - equal to \$5.20 per ton silicon carbide. Thus, each form of silicon carbide will be assigned \$2.60 per ton.

2) Insurance

An annual premium of one-half percent of the fixed investment (\$3.2 million for silicon carbide) would equal \$16,000 or \$1.30 per ton. Each form of silicon carbide will carry \$0.65 per ton.

g) Estimated Manufacturing Cost

It is shown in Table B that crude abrasive silicon carbide can be manufactured at the Reesedale Site for a unit cost of \$157.19 per ton. In general, this is equal to the delivered price for crude abrasive made in Canada and imported duty-free into the United States. As a result, there are not any savings that can be realized by a virgin grain plant near Reesedale.

It is felt that profit is derived on the Canadian operation by the savings in total labor cost, payroll burden charges, depreciation, and overhead expense:

<u>Item</u>	<u>Savings Estimated</u>
Labor	\$2.60/ton crude
Payroll Burden	1.40
Depreciation	8.00
Overhead	<u>3.00</u>
TOTAL	\$15.00/ton crude silicon carbide

These plants are, essentially, primary sources for virgin grain to an affiliated United States company that invested in the Canadian plant many years ago. There appears to be a growing surplus of silicon carbide capacity in Canada because more attractive power rates are found in the Pacific Northwest and in foreign countries (e.g. Norway)

TABLE B

CRUDE ABRASIVE SILICON CARBIDEEstimated Unit Manufacturing Cost

<u>Item</u>	<u>Factor (a)</u>	<u>Unit Price (b)</u>	<u>Unit Cost (c)</u>
Silica Sand, Ton (99% SiO ₂)	1.65	\$ 7.77	\$12.70
Petroleum Coke, T.	1.00	20.00	20.00
Sawdust, Ton	0.170	4.00	0.68
Salt, Lb.	2	0.005	0.01
Electrodes, Lb.	10	0.30	3.00
DIRECT MATERIALS --	--	--	\$36.39
Furnace Power, KWH	7000	0.005	35.00
Other Utilities	--	--	3.70
Other Materials	--	--	17.41
Direct Labor, Men	40	208,000	16.70
Other Labor, Men	27	203,400	16.20
Payroll Burden	25% Total Labor		8.24
Local Taxes & Insurance			3.25
DIRECT PLANT COST PER TON			\$136.89
Depreciation	10% (\$1.600 Mill.Inv.)		12.80
Overhead	5% Sales Price		7.50
UNIT MANUFACTURING COST PER TON			<u>\$157.19</u>

(a) Factor is units per ton crude silicon carbide.

(b) Unit price of item.

(c) Unit cost per ton crude silicon carbide.

2. Silicon Carbide Finished Grit

a) Raw Materials

The basic raw material is crude abrasive grain from either Canada or Reesedale at a unit price of \$157.19 per ton. A factor of one ton crude grain per ton of finished grit is assumed--a 100 percent physical yield.

Chemical reagents for pH adjustment and flocculation of fines are estimated at 20 pounds per ton. The average unit price is 10 cents per pound for a unit cost of \$2.00 per ton finished grit.

b) Conversion

The wide range of finished grit forms are made up of a variety of particle size distributions, physical characteristics (hardness and friability), and chemical analysis (grade). For this reason, essentially no loss of crude abrasive is taken in the finishing operations.

c) Utilities

Estimated usages for the finished grit are:

Refrigeration Power	500 KW
Process Power	750 KW
Ventilation Power	250 KW
Site Facilities Power	<u>500 KW</u>
Total Connected Power	2000 KW
Sanitary Water	25 gpm
Process Water	125 gpm
Cooling Water	50 gpm

Natural Gas
Steam

20,000 CFH
1,000 #/Hr.

The unit cost of utilities required per ton of finished grit based on an output of two tons SiC per hour is:

Auxiliary Power	$50\% \times 2000 \text{ KWH} @ 5 \text{ mills}$	\$5.00
Plant Water	$\frac{150 \text{ gpm} \times 60 \times 20\text{¢}}{1000 \text{ gallons}}$	1.80
Cooling Water	$\frac{50 \text{ gpm} \times 60 \times 5\text{¢}}{1000 \text{ gallons}}$	0.15
Natural Gas	$\frac{20,000 \times 50\text{¢}}{1000}$	10.00
Steam	$\frac{1000 \times 50\text{¢}}{1000}$	0.50
	Hourly Charges	\$17.45
	Unit Cost Per Ton Grit	\$ 8.78

d) Other Materials

1) Maintenance Material

Direct Labor	\$54,000 per year
Maintenance Material	54,000
Unit Cost	\$4.30 per ton grit

2) Miscellaneous Materials

Other Labor = $50\% \times \frac{\$119,200}{12,500 \text{ T}}$

= \$4.78 per ton grit.

3) Fiber drums, plastic liners, and other

packaging items are estimated to be \$20 per ton. The finished grit is sold in 50-100 pounds per container so that

a charge of one cent per pound is realistic.

e) Local Taxes and Insurance

Equal to the unit cost estimated for crude -
\$3.25 per ton.

f) Estimated Manufacturing Cost

It is estimated that finished silicon carbide grit can be manufactured at Reesedale for \$283.60 per ton (see Table C).

C. FUSED ALUMINUM OXIDE

1. Raw Materials

a) Bauxite

Abrasive grade bauxite is used for the regular fused aluminum oxide products and high purity alumina is required for both the semi-friable and white fused aluminas:

	<u>Regular</u>	<u>Semi-Friable(a)</u>	<u>White(b)</u>
Alumina (Al_2O_3)%	94-96	96-98	98.5-99.5
Titanium Oxide (TiO_2)%	2.0-3.5	1.5-2.5	0.0-0.5
Silica (SiO_2)%	1.0-2.0	0.5-1.0	0.0-0.5

(a) A special grade contains 10% ZrO_2 that is needed for grinding stainless steel and high alloy steels.

(b) Pink fused alumina contains 0.05-0.2% Cr_2O_3 . This grade is superior to the while alumina, which is the hardest form, for severe cutting and resistance to physical degradation.

TABLE C

FINISHED GRIT SILICON CARBIDEEstimated Unit Manufacturing Cost

<u>Item</u>	<u>Factor (a)</u>	<u>Unit Price (b)</u>	<u>Unit Cost (c)</u>
Crude Abrasive, Ton	1.00	\$ 157.19	\$ 157.19
Chemical Reagents, Lb.	20	0.10	2.00
Power, KWH	1000	0.005	5.00
Other Utilities	--	--	8.78
Other Materials	--	--	29.08
Direct Labor, Men	40	\$194,000	15.50
Other Labor, Men	27	<u>161,400</u>	12.90
PAYROLL LABOR-25% Total Labor (\$355,400)			7.10
Local Taxes & Insurance	--	--	<u>3.25</u>
DIRECT PLANT COST per ton-finishing step only			\$83.61
Depreciation 10% (\$1.60 million investment)			12.80
Overhead 10% Sales Price			<u>30.00</u>
Total Unit Conversion Cost			\$126.41
Unit Cost - Crude Abrasive			<u>157.19</u>
TOTAL UNIT MANUFACTURING COST PER TON			<u>\$283.60</u>

(a) Factor is units per ton silicon carbide grit.

(b) Unit price of item delivered to plant.

(c) Unit cost is the product of the respective factor multiplied by the unit price, or it is the estimated hourly or annual charges divided by the tons of silicon carbide per hour or per year.

A typical analysis of the abrasive grade calcined bauxite is:

<u>Component</u>	<u>Analysis</u>
Alumina (Al_2O_3), %	86.0 minimum
Silica (SiO_2) (7.5% max.), %	5.0 typical
Loss on Ignition (1.0% max.), %	0.5-1.0 typical
Fe_2O_3 (2.0% max.), %	1.5-2.0 typical
TiO_2 , %	3.22 typical

A refractory grade (87% Al_2O_3 minimum) of super calcined bauxite (RASC) is sold to refractory brick manufacturers in the Kittanning area, which is adjacent to Reesedale. Rail freight on this material from Baltimore is \$6.58 per gross ton (2240 pounds) for a single car with a minimum of 50 tons. A stevedoring charge of 65 cents per gross ton must be added to the rail freight.

A lower rail freight rate of \$4.20 per gross ton is now established for haulage from a northeast ocean port to Niagara Falls. The tonnage shipped to the Niagara Falls area (Canada and United States) permits the low rate for the equivalent of a total load of 1000 tons per train. The calcined bauxites are delivered to Canadian plant sites via either boat or rail shipment for \$30.70 per net ton (2000 lb.).

A typical analysis of the abrasive grade calcined bauxite is:

<u>Component</u>	<u>Analysis</u>
Alumina (Al_2O_3), %	86.0 minimum
Silica (SiO_2) (7.5% max.), %	5.0 typical
Loss on Ignition (1.0% max.), %	0.5-1.0 typical
Fe_2O_3 (2.0% max.), %	1.5-2.0 typical
TiO_2 , %	3.22 typical

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b) Green Petroleum Coke

Green petroleum coke will be obtained from the silicon carbide department because only 25 tons per week is needed.

c) Steel Turnings

From information furnished by West Penn Power, a medium-grade scrap is the classification for a suitable steel scrap (turnings) to form ferrosilicon. This material is quoted at \$26.60 per ton F.O.B. Pittsburgh with an estimated truck haulage charge of \$3.00 per ton. Thus, the delivered price is taken at \$29.60 per ton in the operating cost estimate.

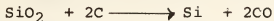
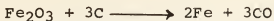
d) Carbon Electrodes

Carbon electrodes are estimated at 15 cents per pound. The 20 inch to 24 inch diameter vertical electrodes are self-supporting from a holder.

2. Chemical Reactions

The aluminum oxide is the least reactive of the many metallic and non-metallic oxides in the bauxite feed. As a result, the iron oxide and silica can be reduced preferentially by a controlled addition of carbon (petroleum coke). Reduction of the titania and/or alumina will take place, however, if excess carbon is present.

The desired reductions are:



It is necessary to add iron metal (steel turnings) in order to obtain a ferrosilicon alloy phase (lower metal layer in melt) that contains a maximum of 15 percent silicon metal (Si).

3 Nominal Design Data

The basic requirements to produce 25,000 tons fused aluminum oxide annually are listed in Table D based on the chemical composition of the raw materials and the conversion of at least 75-80 percent of the contained silica (SiO_2) to ferrosilicon.

4. Utilities

This electrothermal fusion requires only about 2000 KWH per ton crude fused alumina in comparison with 7000 KWH per ton crude silicon carbide. As a result, the furnace power supply is only 7500 kilowatts (KW) to meet the design output of 25,000 tons per year.

A list of the estimated utilities for both crude abrasive and finished grit of fused alumina is:

Utilities - Fused Alumina

		<u>Crude</u>	<u>Grit</u>
Furnace Power	KW	7500	None
Process Power	KW	500	750
Ventilation Power	KW	250	200
Auxiliary Site Power	KW	500	500
Air Compression Power	KW	50	50
Refrigeration Power	KW	<u>500</u>	<u>500</u>
Total Other Power	KW	1800	2000

Power rate - 5 mills per KWH.

A list of the other utilities required is:

	<u>Crude</u>	<u>Grit</u>
Sanitary Water @ 20¢/1000 gals.	25gpm	25gpm
Process Water @ 20¢/1000 gals.	25 "	75 "
Cooling Water @ 10¢/1000 gals.	150 "	50 "
Natural Gas @ 50¢/1000 CF	1000CFH	44,000
Steam @ \$1.00/1000 lbs.	500#/Hr	500#/H

The hourly charges estimated for these other
utilities and the unit cost per ton of crude abrasive and
finished grit are:

	<u>Crude</u>	<u>Grit</u>
Power	\$ 9.00	\$10.00
Process Water	0.60	1.20
Cooling Water	0.90	0.30
Natural Gas	0.50	22.00
Steam	<u>0.50</u>	<u>0.50</u>
Total per hour	\$11.50	\$34.00
Unit Cost per ton (3.5 tons/hour)	\$ 3.28	\$ 9.70

5. Other Materials

The other materials are estimated as follows:

Fused Aluminum Oxide

	<u>Crude</u>	<u>Grit</u>
Maintenance Labor	\$ 96,000	\$ 54,000
Maintenance Material (a)		
Unit Cost per ton	3.84	2.26
Other Labor (b)	114,000	364,000
Miscellaneous Materials (c)		
Unit Cost per ton	2.28	7.28
Packaging Items,		
Unit Cost per ton	5.00	25.00

(a) Maintenance material is equal to maintenance direct labor.

(b) Other labor is total labor exclusive of operators and mechanics.

(c) Miscellaneous materials is 50 percent of other labor.

6. Miscellaneous Plant Expense

a) Local Taxes

\$2.0 million at 65 mills = \$130,000 per year.

25,000 TPY abrasive,

Unit Cost = \$5.20 per ton

Assign \$1.70 per ton of crude abrasive and
\$3.50 per ton of finished grit.

b) Insurance

\$7.1 million at $\frac{1}{2}\%$ = \$35,500 per year.

That gives a unit cost of \$0.45 per ton of crude
and \$0.97 per ton of grit.

c) Miscellaneous Expense

The charges made up of local taxes and insurance

from the above are:

	<u>Crude</u>	<u>Grit</u>
Local Taxes	\$1.70	\$3.50
Insurance	<u>0.45</u>	<u>0.97</u>
Miscellaneous Expense.	\$2.15	\$4.47

7. Estimated Operating Costs

Crude abrasive fused aluminum oxide (virgin grain) can be manufactured for an estimated \$111.17 per ton at the Reesedale site (see Table E). This is about the same as the delivered price of imported material from Canada; namely, \$105-\$110 per ton F.O.B. works plus \$5-\$7 per ton freight. Profit on the Canadian operation is derived from advantages by lower costs for bauxite, power, labor, depreciation, and sales expense. It is not adequate to justify crude abrasive manufacture in the United States. Special grades, however, are made in the United States to develop and to retain process know-how for the more expensive forms.

The wider application of fused alumina in comparison with silicon carbide is made possible by its superior properties and its low cost. The finished grit sells for about \$250-\$400 per ton, which is in agreement with the estimated manufacturing cost (see Table F) of \$234.54 per ton. The diversity of the fused alumina grades

TABLE DFUSED ALUMINUM OXIDENominal Design Data

<u>Item</u>	<u>Factor (a)</u>	<u>Batch</u>	<u>Month</u>	<u>Year</u>
Abrasive Bauxite, Ton	1.15	28.75	2300	28,750
Petroleum Coke, Ton	0.05	1.25	100	1,250
Steel Turnings, Ton	0.08	2.00	160	2,000
Electrodes, Ton	0.02	0.50	40	500
Power (b) KWH	2500	62,500	5×10^6	62.5×10^6
Furnace Load, Ton	1.30	32.5	2600	32,500
Furnace Volume, Cu.Ft.	10.0	250 (Need 12 fusion units 8'Dx6'H)		
Total Batches	0.04	1.0	80	1,000
Fused Alumina, Ton	1.00	25 (c)	2000	25,000
Direct Labor, Employees	40 (4 shifts @ 10 men each)			
Total Labor, Employees	90 out of 314 total at plant.			

(a) Units of item needed per ton fused aluminum oxide.

(b) Three 2500 KW transformers will supply three fusion stations.

(c) Three batches per day will be fused for a nominal daily output of 75 tons fused alumina, or 3.5 tons per hour.

TABLE E

CRUDE ABRASIVE FUSED ALUMINUM OXIDEEstimated Unit Manufacturing Cost

<u>Item</u>	<u>Factor (a)</u>	<u>Unit Price (b)</u>	<u>Unit Cost (c)</u>
Abrasive Bauxite, T.	1.15	\$ 31.00	\$ 35.60
Petroleum Coke, Ton	0.05	20.00	1.00
Scrap Turnings, Ton	0.08	30.00	2.40
Electrodes, Lb.	35	0.15	5.25
DIRECT MATERIALS	--	--	\$ 44.25
Power (7500 KW), KWH	2500	0.005	12.50
Other Utilities	--	--	3.28
Other Materials	--	--	11.12
Direct Labor, Men	40	\$186,000	7.45
Other Labor, Men	50	260,800	6.40
Payroll Burden	25% of Total Labor		5.02
Local Taxes & Insurance			<u>2.15</u>
DIRECT PLANT COST PER TON			92.17
Depreciation	10% (\$3.5 Mill. Inv.)		14.00
Overhead	5% of Sales Price		<u>5.00</u>
UNIT MANUFACTURING COST PER TON			<u><u>\$111.17</u></u>

(a) Factor is units per ton crude fused aluminum oxide.

(b) Unit price per item.

(c) Unit cost per ton crude fused aluminum oxide.

TABLE F

FINISHED GRIT FUSED ALUMINUM OXIDEEstimated Unit Manufacturing Cost

<u>Item</u>	<u>Factor (a)</u>	<u>Unit Price (b)</u>	<u>Unit Cost (c)</u>
Crude Fused Alumina Oxide, Ton	1.00	\$111.17	\$111.17
Chemical Reagents, lb.	20	0.25	5.00
Power (1625 KW)	--	--	2.50
Other Utilities	--	--	6.25
Other Materials	--	--	10.00
Drums & Liners	--	--	<u>25.00</u>
VARIABLE UNIT COST FOR FINISHING STEP			48.75
Direct Labor, Men	40	\$194,000	7.80
Other Labor, Men	50	318,800	12.80
Payroll Burden	25% of Total Labor		5.15
Local Taxes & Insurance			<u>4.47</u>
PLANT COST FOR FINISHING STEP			78.97
Depreciation	10% (\$3.6 Mill. Inv.)		14.40
Overhead	10% of Sales Price		<u>30.00</u>
Total Unit Cost Added by Finishing			\$123.37
UNIT MANUFACTURING COST PER TON			<u>\$234.54</u>

(a) Factor is units per ton fused alumina grit.

(b) Unit price of item delivered to plant.

(c) Unit cost per ton of fused alumina grit.

indicates that it is made to meet the specific requirements of each industrial application.

V. FINANCIAL ANALYSIS

A. ECONOMIC FACTORS INVOLVED

1. Introduction

Usually, the economic potential of a project depends not only upon its technical feasibility, but also upon the commercial life anticipated for the product. The intangible marketing problems and other non-technical factors (e.g. labor productivity, local and state taxes, and community services) must also be studied by management before funds are authorized for a new project. In an ARA project proposal, the primary objective is to benefit the community so that the minimum financial return on the investment might be acceptable.

The estimated fixed capital expenditure for a complete silicon carbide and fused aluminum oxide abrasives plant at Reesedale is \$10.3 million. This agrees with reported plant investments for similar facilities. A 15 percent contingency was included to cover training of operators and technical personnel, technical assistance during start-up, and equipment field changes made during the break-in period.

The total project investment will include the fixed plant investment plus the working capital. The lat-

ter will be estimated by assuming 10 percent of annual sales and 15-20 percent of inventory charges for basic raw materials, in-process materials, and finished goods. Both crude and grit forms of the abrasives represent significant cash outlays for basic raw materials, processing costs, and finishing operations. In addition, the need to maintain an adequate inventory of about 25 grit sizes in two or more grades of each form (Crude and Grit) represents a complex and expensive warehouse situation.

It is desirable to establish the nominal return on the investment and the discounted cash flow for two methods of financing the project:

- (1) Only private capital - 100 percent equity.
- (2) The maximum allowable capital support by the Area Redevelopment Act guide lines--5 percent equity.

The effect of selling price, annual output, and critical cost elements for the synthetic abrasives will be discussed to emphasize the features of the Reesedale plant site.

2. Allocation of Fixed Plant Investment

It was necessary to distribute the common site facilities between the two non-metallic abrasives and, also, between their respective crude and finished grit forms. This was done to obtain a "weighted" cost that

will give reliable estimates of the unit manufacturing costs for the crude form of each abrasive--now imported duty-free from Canada. A summary of the fixed plant investment breakdown is (see Section III):

	<u>Silicon Carbide</u>		<u>Fused Alumina</u>	
	<u>Crude</u>	<u>Grit</u>	<u>Crude</u>	<u>Grit</u>
	(Millions of Dollars)			
Process Equipment	\$0.865	\$0.396	\$0.622	\$0.496
Process Buildings	<u>0.485</u>	<u>0.480</u>	<u>0.450</u>	<u>0.480</u>
Process Total	1.350	0.876	1.072	0.976
Site Facilities	<u>0.350</u>	<u>0.450</u>	<u>0.628</u>	<u>1.197</u>
SUBTOTAL	1.700	1.326	1.700	2.173
Engineering, etc.	<u>0.510</u>	<u>0.396</u>	<u>0.510</u>	<u>0.654</u>
SUBTOTAL	2.210	1.722	2.210	2.827
Contingency 15%	<u>0.331</u>	<u>0.258</u>	<u>0.331</u>	<u>0.425</u>
TOTAL REQUEST	\$2.541	\$1.980	\$2.541	\$3.252

3. Working Capital

Estimated working capital for each form of the abrasives is:

	<u>Silicon Carbide</u>		<u>Fused Alumina</u>	
	<u>Crude</u>	<u>Grit</u>	<u>Crude</u>	<u>Grit</u>
	(Millions of Dollars)			
10% Annual Sales	\$0.125	\$0.250	\$0.150	\$0.450
30-Day Raw Materials	0.350	--	0.300	--
In-Process Material	0.350	0.150	0.300	0.250
Finished Goods	<u>0.175</u>	<u>0.350</u>	<u>0.250</u>	<u>0.550</u>
WORKING CAPITAL	\$1.000	\$0.750	\$1.000	\$1.250

4. Total Capital Required

The total investment required is illustrated by product and form.

	<u>Silicon Carbide</u>		<u>Fused Alumina</u>	
	<u>Crude</u>	<u>Grit</u>	<u>Crude</u>	<u>Grit</u>
	(Millions of Dollars)			
Fixed Capital	\$2.541	\$1.980	\$2.541	\$3.252
Working Capital	<u>1.000</u>	<u>0.750</u>	<u>1.000</u>	<u>1.250</u>
TOTAL INVESTMENT	<u>\$3.541</u>	<u>\$2.730</u>	<u>\$3.541</u>	<u>\$4.502</u>
Fixed Capital	\$4.521		\$5.793	
Working Capital	<u>1.750</u>		<u>2.250</u>	
TOTAL INVESTMENT	<u>\$6.271</u>		<u>\$8.0843</u>	
Fixed Capital	\$10.314			
Working Capital	<u>4.000</u>			
TOTAL INVESTMENT	<u>\$14.314</u>			

5. Annual Sales

This is difficult to estimate accurately for finished grit because the unit sales price is determined by the grit size, grade, and amount of abrasive ordered. A list of a few typical prices made available by the larger firms is given on page V-5.

Silicon carbide grit is 27.5 cents per pound for grain (4-mesh to 200-mesh), 35 to 40 cents per pound for flour, and up to \$2.73 per pound for classified powder with a particle size of 7.5 microns.

<u>Grit Size</u>	<u>Particle Size(Avg)</u>	<u>Silicon Carbide</u>	<u>Fused Alumina</u>	
		<u>Regular(Black)</u> (Sales Price, cents per pound)	<u>Regular Grade</u>	<u>Sand Blasting</u>
4	0.25 inch	27.5	20.5	14
200	74 microns	27.5	22.5	16
280	42 microns	52	--	--
400	26 "	52	46	--
500	21 "	57	--	--
600	16 microns	80	75	--
800	12 "	110	105	--
1000	10 "	203	132	--
1600	9 "	233	--	--
2600	7.5 "	273	--	--
F,2F	Unclassified	35.5	--	27
3F,4F	Flours(minus 200-mesh)	39.0	--	29

These delivered abrasive prices are for a 36,000 pound order in 360-pound drums net weight. Smaller orders cost 1-2 cents more per pound and destinations west of the continental divide have a freight charge of 1.5 cents per pound.

Published data in the Minerals Yearbook for 1962 show an average market price for exported abrasive grit to be:

<u>Item</u>	<u>Silicon Carbide</u>	<u>Fused Alumina</u>
	(Unit Price)	
<u>Crude Grain</u>		
Price/Ton	\$153	\$129
Price/Pound	7.65¢	6.45¢
<u>Finished Grit</u>		
Price/Ton	\$337	\$309
Price/Pound	16.85¢	15.45¢

Of course, the quantity of material exported as finished grit is small compared with the total consumption. It is felt that there is a vigorous and competitive market for crude abrasives (virgin grain). A crude abrasives purchaser will usually prepare finished grit to meet his specific requirements before it is converted into a bonded or coated product.

For estimating purposes it was assumed that the average sales price of finished grit would be about twice the price of crude grain, as a minimum, and 300 percent of the crude grain price as a maximum. The annual sales can be estimated for the design capacity of each abrasive with the unit sales price over a typical range. No attempt was made to specify the distribution of the plant output of each abrasive material for the various finished grit grain sizes, powder sizes, and unclassified flour sizes.

Another item of significance is the amount of crude abrasive that might be sold relative to the amount of finished grit. In general, it was assumed that this new plant would emphasize the manufacture of high quality, finished grit to supply 25-50 percent of the abrasive fabrication firms east and west of Pittsburgh. Some of these firms have been acquired by fully integrated abra-

sive companies who specialize in the manufacture of high-speed grinding and polishing machinery for the metal-working and similar mass-production operations (e.g. prefinished plywood interior and exterior panels).

6. Definition of Terms

- a) Annual Sales Income = NS, where

N = number of units sold per year

S = unit sales price

- b) Manufacturing Cost = M + D + B, in which

M = Direct plant cost = NV + A

N = number of units produced

V = unit variable cost that covers direct charges for raw materials, utilities, and operating labor (in this study).

A = direct plant expense, which includes all labor except operating labor, other materials (maintenance and supplies), local taxes, insurance, and other direct operating charges.

D = Depreciation and amortization charges plus any depletion allowance (applied on a unit basis). Assumed 10 percent of fixed capital.

B = Indirect expense or general overhead charges to cover sales expense, product distribution charges, technical service for customers, research and development, and home office expense.

F = Fixed expense that must be carried regardless of the plant output.

F = A + D + B

- c) Income before Tax = Z = NS - (M + D + B)

Where Z is the net income before tax for the year. Note that the income at the plant level is defined as:

$$P = NS - M.$$

d) Net Income = $Y = (1 - t)Z$, where

Y = Net income after tax

t = Income tax rate applied by Federal government (48%) and Pennsylvania (6%).

$$t = 0.54$$

e) Cash Flow = $R = Y + D$, where

R = Cash derived from operation as net income after tax plus depreciation.

f) Return on Investment = $\frac{Z}{E}$, where

Z = Income before tax

E = Capital expenditure for plant only (exclusive of working capital)

g) Capital Earning Rate = $\frac{Y}{I}$, where

Y = Net income after tax

I = Total plant investment (fixed plus working capital)

h) Nominal Payout Time = $T = \frac{I}{R}$, where

T = Time in years

I = Total plant investment ($I = E + W$, where E = fixed capital and W = working capital)

R = Annual cash flow ($R = Y + D$) or sum of net income after tax plus depreciation.

i) Net Present Value = NPV

This is used in some cases to compare alternate processes or projects on the basis of their present worth. A minimum capital earning rate $\left(\frac{I}{I}\right)$ of 6-15 percent is sometimes selected so that the annual cash flow (R) can be discounted at a specific interest rate over a given period (e.g. 10 percent for 10 years) to determine the net present value of the investment.

Another approach is to determine the number of years needed to recover the total investment on a discounted cash flow basis.

This technique has been emphasized over the last 10-15 years but it is sensitive to the vagaries of marketing that cannot be planned with the high probability desired. In an established industry using old processes for existing products, the net present value approach can be applied with confidence by one of the leading concerns if continuing dominance of its market sector is assured. A newcomer in the marketing area, however, has a lower probability of success unless new technology for an established product offers not only a lower manufacturing cost but also a significantly higher quality product. Thus, the ability to penetrate an existing market or to create a new or expanded market are risk factors (probability of success) that must be applied to any financial analysis.

B. MANUFACTURE OF CRUDE ABRASIVES ONLY

In general, it was found that either crude abrasive, silicon carbide or fused aluminum oxide, can be manufactured at the Reesedale site at, or slightly below, the respective delivered price of material imported, duty-free, from Canada:

	<u>Canadian Supply (a)</u>	<u>Reesedale Site (b)</u>
<u>Silicon Carbide</u>		
Equivalent Cost, per ton	\$161.00	\$157.19

Fused Aluminum Oxide

Equivalent Cost, per ton	113.50	111.17
--------------------------	--------	--------

(a) Estimated delivered price of Canadian material

(b) Unit manufacturing cost (see pages IV-19 and IV-31)

Thus, the out-of-pocket, estimated annual savings in manufacturing crude forms of both abrasives is about \$50,000 to \$100,000. As a result, it can be concluded that the Reesedale site offers no advantage over the existing Canadian crude grain plants because the total investment required would be \$5-7 million (see page V-3). It is of interest, however, that the amount of silicon carbide crude manufactured in the United States has increased during the last ten years and is approaching the total Canadian output. The Canadian plants are operating at a "reported" lower output of rated capacity--down from

70 percent to 45 percent. Despite this apparent operating situation, the Canadian manufacturers are installing new and larger furnace units. In addition, new facilities have been installed or planned for both foreign and domestic plant sites with low cost power. The Carborundum Company built a plant in the Pacific Northwest to utilize the attractive power rate of roughly 2 mills per kilowatt hour. This rate is about 50 percent of the Canadian rate (4 mills) and 40 percent of the Reesedale rate (5 mills). The unit power cost savings of \$17.50 to \$21.00 per ton silicon carbide offsets the additional freight charge from the Pacific Northwest area to Carborundum's crude grain customers in the middle west and Pacific Coast regions of the United States.

The primary cost element is power so that every effort must be made to obtain a power rate of 4 mills per KWH (20,000 KW supply with 90-95 percent load factor on an interruptible basis). A four-mill rate would be equivalent to that offered by other geographical regions to permit competition with the Canadian hydro-power supply. A unit power cost reduction of \$7 per ton at Reesedale results in a total estimated savings of \$87,500 per year for silicon carbide crude.

Fused aluminum oxide has a unit power cost of

only \$12.50 per ton so that a power rate reduction of one mill per kilowatt hour is equivalent to \$2.50 per ton savings. For an annual output of 25,000 tons per year, the Canadian operation would show an out-of-pocket savings over Reesedale of \$62,500 for power alone.

The cost of abrasive grade bauxite, however, is the primary cost element for fused aluminum oxide crude abrasive. Delivery of the basic raw material at the plant site by ocean-going vessels might be another significant advantage of the Canadian operations for fused aluminum. Only the pure and special grades of fused alumina are made in the United States--about 15 percent of the total North American output.

A summary of the financial data is given in Table G for making crude abrasives only at the Reesedale site. The nominal payout time is estimated at 14.3 years for crude silicon carbide and 11.9 years for crude fused aluminum. The critical items in the study are the sales prices assumed for the crude abrasives and the overhead (indirect expense) applied at five percent of the market price for each crude abrasive.

The effect of the average sales price is calculated to show the conditions that are normally required to justify a new venture. The average sales price is

based on a constant ratio of 2/1 for the output of crude fused aluminum oxide/crude silicon carbide, which is the nominal design ratio for the proposed Reesedale plant. We have reason to believe from discussions with consultants and customers in this field that an average price of \$140-150 per ton F.O.B. works is being quoted for the non-metallic crude abrasives.

The following terms are applied to determine the desired financial information:

$$\text{Annual Sales} = 37.5 (10^{-3}) \times S, \text{ \$Million}$$

$$Z = \text{Income before tax, \$Million}$$

$$= 37.5 (10^{-3}) \times S - \$4.742 \text{ MM}$$

$$Y = (1-t) Z, \text{ where } t = 48 + 6 = 54\% \\ \text{combined federal and state income tax rates}$$

$$R = \text{Cash Flow} = Y + 0.508, \text{ \$million}$$

$$\text{Nominal Return on Investment} = \frac{Z}{E}, \text{ percent fixed capital}$$

$$\text{Capital Earning Rate} = \frac{Y}{I}, \text{ percent total investment}$$

$$\text{Payout Time} = \frac{I}{R}, \text{ years.}$$

Financial justification of the crude abrasives project might be realized if the average sales price can be increased from \$129 to \$135 per ton of the combined total output. This generates an additional \$98,000 of cash flow

and shows a nominal payout time of 10.8 years. This is considered to be a marginal case for an established manufacturer in the abrasive field because the probability of marketing the product is 75-90 percent.

If an average crude grain sales price of \$140 per ton were acceptable to the trade, then the return on the investment would be 10 percent and the payout time 9.6 years. In this operation, the relatively high working capital required represents a major share of the total investment assumed. If only the fixed capital is considered the new capital required, the payout time is reduced from 9.6 to 6.9 years.

The annual "break-even" output for the combined crude abrasives is 28,700 tons per year (76.5 percent design capacity) at the "plant level" (out-of-pocket costs only) for an average unit sales price of \$140. The operating level must be increased to 34,000 tons per year (90.8 percent design capacity) if the direct plant costs plus depreciation and indirect expense are made equal to the annual sales--zero income.

TABLE G

FINANCIAL ANALYSIS

Manufacture of Crude Abrasives Only

<u>Sym- bol</u>	<u>Item</u>	<u>Silicon Carbide</u>	<u>Fused Aluminum Oxide</u>
N	Annual Output, Tons	12,500	25,000
S	Sales Price, \$/Ton	161.00	113.50
NS	Annual Sales, \$Million	2.013	2.838
E	Fixed Capital, \$Million	1.600 (a)	3.482 (a)
W	Working Capital, \$Million	<u>1.000</u>	<u>1.000</u>
I	Total Investment, \$Million	2.600	4.482
U	Direct Unit Cost, \$/Ton	136.89	92.17
M	Plant Cost, \$Million	1.711	2.304
D	Depreciation, \$Million	0.160 (b)	0.348 (b)
B	Overhead, \$Million	0.094 (c)	0.125 (c)
O	Manufacturing Cost, \$Mill.	1.965	2.777
Z	Income Before Tax, \$Mill.	0.048	0.061
Y	Income After Tax, \$Million	0.022	0.028
R	Cash Flow, \$Million	0.182	0.376
<u>Z</u> <u>E</u>	Return on Investment, %	3.00	1.75
<u>Y</u> <u>I</u>	Capital Earning Rate, %	0.85	0.63
T	Payout Time (<u>I</u>), Years R	14.3	11.9

(a) Allocation of total capital by fraction of total sales

(b) Depreciation is based on 10 percent of fixed capital

(c) Assumed 5.0% of sales price for overhead charges.

C. CONVERSION OF CRUDE ABRASIVE TO FINISHED GRIT

Virgin grain of each crude abrasive can be delivered to the Reesedale site at a price equivalent to that for crude material manufactured at the proposed plant. The economics of converting crude material into the respective finished grit indicates that this operation can be profitable, even under the conditions assumed for the pessimistic case.

The unit plant conversion costs are \$83.61 per ton for silicon carbide and \$78.97 per ton for fused aluminum oxide. The total fixed capital expenditure is \$5.232 million, with \$1.600 million for silicon carbide and \$3.632 million for fused alumina. The working capital is \$2.0 million so that the total plant investment is \$7.232 million. The assumed overhead is \$30 per ton for each form of grit.

Sales prices of \$337 per ton silicon carbide and \$309 per ton fused alumina are considered the most probable market prices because they are the average of United States exported grit (\$318 per ton in 1962). In contrast to these pessimistic values, another set of sales prices has been assumed for the optimistic case. The latter is based on published list prices for finished grit in the plus 200-mesh screen sizes (\$550 for silicon carbide and

\$425 per ton for fused alumina) available from the domestic manufacturers.

It should be pointed out that the proposed Reesedale plant would emphasize the manufacture of grit powders (classified fines or particle sizes less than 74 microns) and grit flours (unclassified fines). The powders command a unit sales price at least twice that for the plus 200-mesh screened material. When the high-precision lapping and polishing powders (a particle size below 10-microns) are purchased, the unit price is 400 to 500 percent of the grit grain price. The physical distribution of the grit sizes sold is not available so that the assumed prices for the optimistic case are believed to be conservative.

Under the pessimistic conditions, the annual sales will be \$7.845 million if 12,500 tons of silicon carbide is sold at \$337 per ton and 25,000 tons of fused alumina at \$309 per ton. The cost of the basic raw materials--both forms of the crude abrasives--will be \$4.742 million for either Canadian or Reesedale material. The mill conversion direct costs will total \$3.019 million, \$1.045 million and \$1.974 million respectively for silicon carbide and fused alumina.

Thus, for the pessimistic case, the annual in-

come at the plant level will be \$11.925 million minus \$7.261 million or \$4.164 million.. This is more than enough to carry the depreciation of \$0.523 million and overhead of \$1.125 million, a total of \$1.648 million.

The annual income before tax will be \$2.516 million that represents a nominal return on the fixed investment of 48.0 percent. The net income after tax will be \$1.157 million, which is equal to a capital earning rate of 15.9 percent and a payout time of 4.3 years.

From these estimates it is shown that the current supply of crude abrasives from Canada allows an excellent return on the investment. Also, significantly less new capital is needed if an established foreign source has adequate capacity to meet the demand.

Lower average prices for finished grit might be necessary as the market conditions become depressed in times of oversupply. The "break-even" average grit price is the total manufacturing cost (\$9.409 million) divided by 37,500 tons or \$250 per ton.

An average sales price of \$318 per ton (for the pessimistic case) will permit a lower plant output of 29,600 tons per year, or 78.8 percent of design capacity, for the "break-even" situation under these conditions.

From the attractive financial return calculated,

a new crude abrasive plant, in the United States cannot be justified unless the unit cost reduction for crude is enough to repay the new capital expenditure in 5-8 years. Improved techniques for fabricating non-metallic abrasive articles offers an advantage for high-speed machining over the metallic abrasives in many applications. Special grades of fused aluminum oxide have penetrated this market area. The outstanding physical characteristics, such as hardness and high melting point, of such non-metallic abrasives has allowed a diversification of the product line and increased sales from expanded usage.

D. MANUFACTURE OF FINISHED ABRASIVE GRIT

It can be shown that conversion of virgin grain from Canada into finished grit offers an excellent return on the fixed capital investment (16.1 percent) and a short payout time (4.3 years) for the pessimistic case, in which \$318 per ton of finished grit is the average sales price. The effect of manufacturing the crude at Reesedale, which is a "break-even" situation with purchased Canadian crude grain, will be illustrated by estimating the financial return on the combined operations.

A breakdown of the data needed to analyze the economic potential is given in Table H. It has been pointed out that the fixed capital charged to the crude and grit

forms of the abrasives was an allocation of the total plant investment according to the relative sales value of the abrasives. This is realistic because the burden of the site facilities must be carried by the fused alumina, in its many grades, that are produced in an amount equal to twice that of the silicon carbide.

The additional capital expenditure required to manufacture each of the captive crude grains at Reesedale increases the cash flow. The nominal return on the investment, however, is reduced from an estimated 41.5 to 20.8 percent for silicon carbide and 51.5 to 26.2 percent for fused aluminum oxide. The payout time for silicon carbide is increased from 5.0 to 7.9 years and for fused aluminum oxide from 4.0 to 6.0 years (see Table H).

Thus, it is evident that the current economics favor a continued importation of crude abrasives from Canada on a duty-free basis because total manufacture of the two synthetic abrasive crude grains requires a capital expenditure of \$14.314 million vs. \$7.232 million for conversion only of crude grain to finished grit.

Evidently, the dominance of the Canadian crude grain supplies has been established over an extended period, at least 30-35 years, and every effort can be expected to maintain this unique position. In time, however, labor

TABLE H

FINANCIAL ANALYSIS

Manufacture of Finished Abrasive Grit

<u>Sym-</u> <u>bol</u>		<u>Silicon</u> <u>Carbide</u>	<u>Fused</u> <u>Aluminum</u> <u>Oxide</u>
N	Annual Output, Tons	12,500	25,000
S	Sales Price, \$/Ton	337	309
NS	Annual Sales, \$Million	4.213	7.725
E	Fixed Capital, \$Million	3,200	7.114
W	Working Capital, \$Million	<u>1.750</u>	<u>2.250</u>
I	Total Investment, \$Million	4.950	9.364
C	Cost of Crude, \$Million	--	--
M	Plant Cost, \$Million	2.756	4.278
D	Depreciation, \$Million	0.320	0.711
B	Overhead, \$Million	<u>0.469</u>	<u>0.875</u>
O	Operating Cost, \$Million	3.545	5.864
Z	Income Before Tax, \$MM	0.668	1.861
Y	Income After Tax, \$MM	0.307	0.856
R	Cash Flow (Y+D), \$MM	0.627	1.567
<u>Z</u> E	Return on Investment, %	20.8	26.2
<u>Y</u> I	Capital Earning Rate, %	6.2	9.1
T	Payout Time (<u>I</u>), Years R	7.9	6.0

Finished Grit Via Conversion

Return on Investment, %	41.5	51.5
Capital Earning Rate, %	13.1	17.5
Payout Time, years	5.0	4.0

rates, freight charges, and other factors will permit domestic output of the crude grain to compete with Canadian material.

For example, the economic potential of domestic operations in which crude abrasive grain would be manufactured might be several new or increased applications of silicon carbide in the non-abrasive areas. This accounts for only 10-15 percent of the total silicon carbide market so that intensive research and development work has been authorized during the last 10 years. Some of these areas include chemical processing equipment (special parts), the paper industry, and high-temperature, gas-cooled fuel elements for nuclear power reactors.

The Carborundum Company has announced a sintered KT silicon carbide that is not only impermeable, but also non-porous, along with greater resistance to heat, wear, and corrosion. It is a high-density, self-bonded abrasive that is typical of the type of research and development required to improve the quality of a product and to find new uses. Similar applications have been found in the national space program for lining nozzle throats and in building other components. These special applications, however, are limited in annual tonnage so that industrial applications must be developed to achieve an expanding

market position.

E. NET PRESENT VALUE METHOD

This technique determines the discounted cash flow for a project over a stipulated period of time and at an assigned interest rate. It is considered more sophisticated than the nominal methods of financial analysis usually employed. Its use by management will be illustrated for a comparison between conversion and manufacture of the synthetic abrasives on an overall, combined basis.

The total annual finished grit output will be 37,500 tons and an average sales price of \$318.33 per ton for the combined abrasives. As described previously (see page V-3), the major difference in these two processing approaches is the total capital investment required. Conversion of the crude grain can be done in a new plant for a capital investment of \$7.232 million, which is about half of that needed for the integrated manufacture of both crude and grit abrasives.

Cash flow for a given year is the total cash income minus the cash outflow. The present value in any given year is the product of the cash flow and a discount factor, which depends upon the interest rate and the time interval. Sources of capital include depreciation and net income after tax plus any other financial allowances. A

decrease in capital is fixed plant investment, provision for working capital, and financial charges for funded debt (interest).

Good bonds and preferred stock yield about five percent so that this is a minimum interest rate for any commercial venture. Most industries demand 8-10 percent return to justify a new capital expenditure. Some outstanding growth industries will not consider a capital expenditure unless a 15 percent return is exceeded.

For synthetic abrasives it is felt that a 10 percent return over a 10-year period should be realized on any new capital invested. Thus, the net present value will be based on factors for a 10 percent interest rate.

For silicon carbide the 10-year net present values illustrate that the conversion of crude grain to finished grit is positive but that the integrated manufacture is always negative:

<u>Interest Rate</u>	<u>Factor</u>	<u>Net Present Value</u>	
		<u>Conversion^(a)</u>	<u>Manufactured^(b)</u>
5%	7.723	\$1.25 million	\$(0.14) million
10%	6.144	0.51 "	(1.11) "
15%	5.019	0.01 "	(1.81) "

(a) Investment is \$2.350 million; R is \$0.467 million

(b) Investment is \$4.950 million; R is \$0.627 million

Fused aluminum oxide shows more commercial potential because of the 25,000 tons yearly output and the

lower unit manufacturing cost. The net present value is positive in all cases except for an interest rate of 15 percent for the manufactured case:

<u>Interest Rate</u>	<u>Factor</u>	<u>Net Present Value</u>	
		<u>Conversion(a)</u>	<u>Manufactured(b)</u>
5%	7.723	\$4.53 million	\$2.74 million
10%	6.144	2.62 "	0.24 "
15%	5.019	1.22 "	(1.46) "

(a) Investment is \$4.882 million; R is \$1.219 million

(b) Investment is \$9.364 million; R is \$1.567 million.

The manufacture of both synthetic abrasives cannot be justified on the basis of the net present value in comparison with the conversion of Canadian crude:

<u>Interest Rate</u>	<u>Factor</u>	<u>Net Present Value (10-years)</u>	
		<u>Conversion</u>	<u>Manufactured</u>
5%	7.723	\$5.87 million	\$2.59 million
10%	6.144	3.37 "	(0.91) "
15%	5.019	1.27 "	(3.31) "

Accelerated depreciation of a new plant is permitted to take advantage of the higher cash flow generated during the early years. Thus, there is a possible overall financial gain by a depreciation charge above the straight line method (e.g. by sum-of-digits depreciation) despite an initial decrease in net income after tax.

Another method is to depreciate and amortize the total capital investment instead of the fixed capital only. One reason for this method is that working capital

is an equivalent capital reserve that must be invested to derive the maximum income and cash flow. There is no significant charge in the net present value for these depreciation methods in the case of silicon carbide grit via conversion. The cash flow is increased from \$0.467 to \$0.469 million, which validates the unattractive nature of silicon carbide alone.

In contrast, fused aluminum oxide shows a higher cash flow (\$1.268 vs \$1.219 million) by depreciating the total investment. Then the net present value for 10 percent interest and 10 years would be increased by \$301,000--from \$7.5-7.8 million. Every possible method is usually studied to determine that which gives the maximum cash flow.

Manufacture of finished grit will show an estimated reduction in the relative net present value of \$4.28 million in comparison with conversion of crude grain only. Expressed in another way, the lower investment for conversion of crude abrasives will generate an excess of \$3.37 million after 10 years when the cash flow is discounted at a 10 percent rate. The higher investment of \$14.314 million to manufacture crude abrasives has not paid off the original investment after 10 years and the net present value is negative at \$0.91 million.

F. EQUITY AND FUNDED DEBT

All of the data have been based on the use of only private capital for both fixed plant investment and the working capital. One reason for this assumption was that there is usually adequate surplus capital accumulated as a reserve or, if desired, adequate funds can be borrowed from outside sources at a low rate of interest if stock issues or debentures are considered more expensive capital sources. Review of the financial condition of the major integrated abrasive manufacturers shows that any new project can be supported if the marketing and financial analysis show an adequate return.

The ARA can contribute a significant portion of the fixed capital (up to 65 percent of the total fixed capital required) but none of the working capital. It is stipulated that an ARA project can be obtained with as low as 5 percent equity, provided local banks and state agencies or equivalent provide the remaining 30 percent of the fixed capital. The working capital might be supplied by a federal agency (Small Business Loan) and/or local banks if the project has sufficient economic potential.

A sinking fund is used to retire any capital that is borrowed. In addition, the annual interest charges

on the principal amount borrowed must be paid. An interest rate of 5 percent is adequate for all possible sources of capital--banks, state industrial development agencies, and federal agencies. A depreciation charge of 10 percent of the total investment will cover not only the annual capital needs for modification and rearrangement of the equipment and buildings but, also, the sinking fund payment to amortize the debt and the interest charges on the debt principal.

It will be assumed that the borrowed capital will be \$5 million and \$10 million for the two cases described in Section V Part E, which is a comparison of conversion of crude with manufacturing grit for the combined synthetic abrasives operation.

The interest charges are deductible for income tax purposes and a tax benefit is derived as a result. The annual interest charges can be assumed as 5 percent of the principal amount borrowed to build the plant. To this is added an annual sinking fund deposit, which earns interest at 5 percent, that is compounded and will yield the capital funds borrowed at the beginning of the 10-year period. For a 5 percent interest rate, the 10-year sinking fund annual deposit will be 7.95 percent of the principal amount borrowed. Thus, the combined annual amorti-

zation charges will be 12.95 percent--the sum of 5 percent interest plus the 7.95 percent sinking fund deposit to repay the principal in 10 years.

Funded capital distorts only the nominal return on the equity capital invested because the income after tax and the cash flow remain unchanged. For an equity of 32 percent of the total investment, the nominal return on the investment is 115.0 percent for conversion of crude grain. The capital earning rate is 16.3 percent and the payout time is 4.4 years, which are the same as for 100% equity. A summary of the data is:

	<u>Finished Grit (\$318 per ton)</u>			
	<u>Conversion</u>		<u>Manufactured</u>	
<u>Equity Basis:</u>	<u>100%</u>	<u>32%</u>	<u>100%</u>	<u>32%</u>
Return on Investment, %	48.3	115.0	24.6	62.0
Capital Earning Rate, %	16.1	16.3	8.2	8.4
Payout Time, Years	4.3	4.4	6.6	6.7

G. LEASED FACILITIES

Participation by a state, regional, or municipal industrial development agency has created new plant facilities that can be wholly or partially leased by the industrial operator. If the bond issue can be classified as "tax-free" and a 25-year period taken for retirement of the bonds, only 6.08 percent of the principal must be set aside annually to return the bond principal and interest.

For the combined conversion of crude to grit only, the 6.08 percent of the total investment (\$7.232 million) would equal \$0.440 annual amortization charges (\$0.523 for 100% equity). The annual total manufacturing cost becomes \$9.326 million and the annual income before tax \$2.612 million. The annual income after tax is \$1.202 million, only \$39,000 greater than in the case of 100 percent equity.

It is believed that indirect financial gain becomes evident in the community from the payroll derived from the sponsored project. This accounts for the availability of community and state aid exclusively to finance completely the fixed capital for plant facilities. Many states have encouraged this approach, coupled with tax-free period of operations, to attract new industries. Recently, this was announced by Governor Scranton of Pennsylvania so that the problem of securing capital has been reduced to a minimum.

VI. CONCLUSIONS AND RECOMMENDATIONS

Conversion of the crude abrasives virgin grain to finished grit can be justified for the Reesedale plant. For a total investment of \$7.232 million, the estimated return on the fixed capital of \$5.232 million is 48.3 percent. The capital earning rate is 16.1 percent, which is the net income after tax divided by the total investment. The payout time is 4.3 years based on the annual cash flow and the total investment.

It was decided to use an average sales price of \$318 per ton of finished grit for the pessimistic market case because it agrees with the average price for the synthetic abrasives exported from the United States. This assumption is validated by a discounted cash flow analysis that shows a negative \$0.91 million for grit from manufactured crude and a positive \$3.37 million for grit from converted crude. It is felt that the dominant position in the crude abrasives market will be maintained by Canada for the regular grades of synthetic abrasives.

There is a high degree of confidence in the financial analysis for the manufacture of crude abrasives because the Canadian usages of raw materials and utilities are available along with published prices for the crude

grain exported to the United States.

In the financial analysis for the finished grit operations, however, it was necessary to select a reliable range of sales prices. The pessimistic case is considered the most probable for the bulk of the material marketed--an average price of \$318 per ton based on a ratio of one/two for the annual output of silicon carbide (\$337 per ton) and fused alumina (\$309 per ton). In general, this is in agreement with the data extracted from the annual reports of the primary grit producers, which showed an average income before tax of 8-12 percent of sales.

The optimistic case represents the average sales price for specialized abrasive grit materials that are sold to fabricators of abrasive items and machines. Production and/or sales data on grit cannot be published because of the limited number of manufacturers. As a result, the finished grit price lists issued by the primary abrasive suppliers are considered the best reference for the optimistic sales price. The grit grain (screened fractions) are listed at about \$550 per ton for silicon carbide and \$425 per ton for fused alumina.

Despite the inability to justify a crude abrasives plant at Reesedale, it is suggested that consumers

of virgin grain, as well as purchasers of finished grit, give careful consideration to production of not only finished grit at Reesedale but also crude grain. The specific problems and areas of interest of each customer for abrasive crude and grit make an independent analysis mandatory.

New and improved grades of both synthetic non-metallic abrasives are premium items that command prices equal to, or above, those assumed for the optimistic case. An average sales price of \$418 per ton for the Reesedale output would show an additional gross income of \$3.750 million, an extra \$1.707 million income after tax, and a total cash flow of \$3.393 million. The payout time then becomes 4.23 years, which is equivalent to the 4.3 years for conversion of crude to regular grades of grit.

RECOMMENDATIONS

1. A synthetic abrasives plant with only 10-20 percent of the design capacity should be built initially to supply customers within 250 miles of Reesedale. From 50-100 employees would operate this modest facility for regular grades but, in particular, for special grades of finished grit. A capital expenditure of \$2.5-5.0 million will provide one-third of the electric furnace units, only one of the grit finishing facilities (for campaign-

ing either silicon carbide or fused aluminum oxide), and none of the auxiliary buildings. Expansion to its design capacity would follow as needed.

2. It is imperative to emphasize the manufacture of special grades of finished grit that will sell at \$400, or more, per ton. First, a market must be established for these special grades after the ability of the key operating group to meet the rigid specifications has been demonstrated. Then, a decision can be made for the type and capacity of abrasives plant best suited for the Reesedale site.

3. It is believed that a suitable operator for the proposed Reesedale plant will be one of the major integrated abrasives manufacturers, or a group of independent fabricators of abrasives that purchase crude and/or grit.

ECONOMIC DEVELOPMENT ADMINISTRATION

TECHNICAL
ASSISTANCE
PROJECT

U.S. DEPARTMENT OF COMMERCE

FEASIBILITY STUDY OF CHEMICAL INDUSTRY
IN
SOUTHWESTERN PENNSYLVANIA

PHASE III

POLYVINYL CHLORIDE PLANT

September 1966

"This technical assistance study was accomplished by professional consultants under contract with the Economic Development Administration. The statements, findings, conclusions, recommendations, and other data in this report are solely those of the contractor and do not necessarily reflect the views of the Economic Development Administration."

Prepared By:

SINGMASTER & BREYER
235 East 42nd Street
New York, N.Y. 10017

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Figure V-2 - PVC-Carbide-Acetylene Flow
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Figure V-3 - Flow Diagram - PVC From
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I. REPORT IN BRIEF

This report presents a technical and economic study and develops the investment requirements and the profitability of a "grass roots" chemical complex located in southwestern Pennsylvania to produce 300 million pounds (150,000 tons) per year of polyvinyl chloride (PVC).

A petrochemical process based on petroleum naphtha and chlorine is shown to be the most economic method for this complex based on comparison with: a) the carbide acetylene approach at the same location; and, b) the propane chlorine route at a Gulf Coast location. Vinyl chloride manufacture by the latter route at Gulf Coast locations accounts for most of the recent expansion in this field.

Savings in the over-all transportation expense is the major factor which contributes to the feasibility of the petroleum naphtha approach in competition with Gulf Coast manufacture of vinyl chloride. The geographical pattern of the manufacture and consumption of vinyl chloride provides the basis for the great significance of transportation costs. Fundamentally, with basic raw materials located on the Gulf Coast and the market for the finished resin in the northeast, it is cheaper to ship naphtha by river barge than vinyl chloride by rail.

Additional savings in cost of utilities in southwest

Pennsylvania versus the Gulf Coast also contributes to the feasibility of the petroleum naphtha approach.

Polyvinyl chloride was selected as a promising product for a chemical complex in southwestern Pennsylvania because the region, particularly at Reesedale, locally offered the raw materials (bituminous coal, salt and limestone) and low cost power (at 4 mills per KWH) that are necessary for the carbide-acetylene approach and, further, because the region is centrally located with respect to consumption of PVC resin. The strong annual growth of PVC consumption, averaging over 200 million pounds per year, was another factor in selecting PVC. The carbide-acetylene approach was studied in detail because of this.

In the later stages of the study, information was uncovered on a newly developed process using petroleum naphtha - the Kureha Naphtha Chlorine Process - which, compared to the carbide-acetylene approach, requires lower investment and labor costs and can tolerate higher power costs. Further, unlike other petrochemical processes for vinyl chloride, such as the propane chlorine approach, the Kureha Naphtha Chlorine Process does not produce chemical by-products and therefore does not have to be located adjacent to other chemical complexes for economic utilization of these by-products.

This report presents a study of the investment required and profitability of a naphtha-based chemical complex to produce 300 million pounds per year (150,000 tons) per year of polyvinyl chloride (PVC). The chemical complex is based on petroleum naphtha barge transported from the Gulf Coast, local bituminous coal, and salt and competitive power (at 5.5 mills per KWH). With the newly developed technology of this Japanese process and the geographical and raw material advantages of southwestern Pennsylvania, such a complex would be economically competitive with processes based on petroleum and natural gas raw materials at a Gulf Coast location. The proposed complex would consume local raw materials as follows: 450 tons per day salt, 850 tons per day bituminous coal, and power at 60,000 KW.

The reference design for the naphtha-based complex is based on the installation of a "grass roots" facility with salt wells, caustic-chlorine manufacture, air separation unit, partial oxidation of naphtha, vinyl chloride monomer manufacture and purification and polyvinyl chloride manufacture for a fixed capital investment of \$40.6 million. The working capital required is \$3.5 million, giving a total estimated investment of \$44.1 million. A payout time of 5.82 years is required to recover the total new investment. The financial analysis assumed a sales price for PVC of

10-1/2 cents per pound as an average over the next ten years and a net revenue of \$40 per ton of by-product caustic soda. It was assumed that no revenue would be obtained from by-product hydrogen and no provision was allowed for royalty payment on the Kureha Naphtha Chlorine Process.

It must be pointed out that the Kureha Naphtha Chlorine Process as yet is not well established. Only one commercial application is installed in Japan and only limited process information is available in the United States. Complete endorsement of this process for use in southwestern Pennsylvania cannot be made until the available information is substantiated and further information on the quality of resin derived from this process is available. However, for a firm considering expansion of polyvinyl chloride, the Kureha Process in southwestern Pennsylvania offers opportunities for economic advantage.

II. INTRODUCTION

A. PURPOSE AND SCOPE

This report has been prepared for and is the property of the U. S. Department of Commerce, Area Redevelopment Administration, Washington, D. C. 20230.

This report is part of Phase III of an over-all program to determine the feasibility of additional chemical industry in southwestern Pennsylvania. The previous phase, Phase II, selected polyvinyl chloride resin as one of a number of promising areas for future development. Polyvinyl chloride was selected because of the local availability of low cost raw materials - bituminous coal, coke, limestone and salt - and because the anticipated growth of the markets of both PVC and caustic soda appeared to be sufficient to absorb the output of a facility employing the carbide-acetylene route that would consume power at a sufficiently high load (100,000 KW) to obtain a power rate of four mills per KWH.

The purpose of this report is to establish the economic feasibility of producing polyvinyl chloride in southwestern Pennsylvania by the carbide-acetylene route or any other process that would establish a competitive operation in southwestern Pennsylvania.

B. MARKET SURVEY

1. Size and Growth of Market

The market for polyvinyl chloride in the United States has been increasing at a growth rate of 16 per cent per year since 1955. The current PVC resin demand is approximately 2.0 billion pounds per year. By 1970, it is forecast that this market will have expanded to 3.6 to 4.2 billion pounds per year. Current production capacity is estimated to be about 1.8 to 2.2 billion pounds per year. On a national basis, therefore, it can be seen that a need exists for annual increases in manufacturing facilities of about 500 million pounds per year. Resin output would be readily absorbed in the marketing system and would serve to satisfy the higher industrial and consumer demand envisioned.

That market growth of PVC is sufficient to provide justification for large, efficient vinyl chloride plants is borne out by recent announcements of planned expansions. Announcements by Dow Chemical and Stauffer-Conoco in the last quarter of 1965 indicate that vinyl chloride plants are planned with capacities of 500 and 700 million pounds per year. The reference design of 300 million pounds per year of PVC selected for Reesedale in southwestern Pennsylvania is consistent with this trend.

Firms planning such large units expect the higher

efficiency of these plants to yield profits even at the lower price levels which are projected as necessary to provide a market for the increased output. The history of the market growth of PVC in the 1960's shows a greater rate of growth as the price lowered. PVC, which currently has an average unit value of 16 cents per pound has been projected to have an average unit value of 13 cents per pound by 1970 with a substantial part of the output available at 10 to 11 cents per pound at that time. Correspondingly, this trend will put pressure on the price of vinyl chloride monomer whose only outlet is in PVC. The average unit value of vinyl chloride monomer has been projected to reduce to 5-1/2 cents per pound by 1970 from the current 6.2 cents per pound, based on a substantial part of the output to be available at five cents per pound.

2. Uses

The major uses of polyvinyl chloride resins are in calendering and extrusions, flooring, sheeting, furniture, housewares, luggage, extruded wire and cable covering and coatings on paper and textiles. Major future markets are expected to develop in building products and packaging, e.g., PVC containers, rigid flat and corrugated sheeting-siding, rainwear garments, process piping and ductwork. In regard to its use in building materials, acceptance of

polyvinyl chloride by local building codes in general will have to be obtained for major growth in this area. It is believed that this acceptance will be forthcoming on the basis of recent approval of plastic pipe for plumbing by Cleveland and St. Louis building codes. In addition, use of rigid vinyl panels have been code-approved in 130 key cities in 38 states.

3. Geographical Characteristics of the Market

Production facilities for polyvinyl chloride resin have been primarily located in the industrial northeast sector of the nation. Approximately 75 per cent of United States polyvinyl chloride capacity is in this area, and announced plans for new facilities indicate that this trend will continue. The remaining capacity is situated on the Gulf and West Coasts. Production of raw vinyl chloride monomer, however, is centered in the Gulf Coast area. Rail or barge shipment of the vinyl chloride monomer in bulk lots at special freight rates is thus required from the Gulf Coast to the northeast consuming area. The basic question to be answered here is whether or not the cost of polyvinyl chloride produced in the nine-county area of southwestern Pennsylvania would be competitive with the Gulf Coast delivered material, assuming a constant market price for the polyvinyl chloride resin. Raw material costs and their

availability, investment requirements, freight charges and the relative merits of alternate manufacturing processes must be taken into consideration.

4. Expected Average Selling Price of PVC and Caustic

An average selling price of 10.5 cents per pound has been assumed for the polymer. This selling price is approximately one-half the difference between a spot market price of 14.0 cents per pound (as reported, not listed, in the "Oil, Paint and Drug Reporter" of August 2, 1965) and the estimated unit manufacturing cost of 8.10 cents per pound. In addition, reports that the polymer is being sold on a large volume contract basis at 10 to 11 cents per pound were considered in assuming a nominal selling price. It is believed that the 10.5 cents per pound price will serve to compensate for price reductions that are expected by 1970 in the vinyl monomer and polymer markets. A price below ten cents per pound of PVC resin is anticipated for the expanding market after 1970.

The revenue from the sale of by-product caustic soda as the 50 per cent liquid was based on a net average value of \$40 per ton of 100 per cent caustic soda for the entire plant output after distribution and transportation costs. This is probably the lowest level of revenue that would be received from the marketing of caustic soda.

C. COST COMPARISON OF VINYL CHLORIDE PROCESSES

1. General

The main consideration in an economic comparison of the Gulf Coast with southwestern Pennsylvania as a site for a vinyl chloride monomer plant is the "source of carbon". The "carbon source" is a particularly significant element in the economics of the proposed plant for carbon is a major raw material and is also the ultimate source of energy for electrical power. The sources of carbon on the Gulf Coast are petroleum or natural gas fractions, while in southwestern Pennsylvania, coke and bituminous coal provide the indigenous sources of carbon. Processes currently in use to manufacture vinyl chloride require acetylene or ethylene as a carbon containing intermediate. The cost of power at both locations also is dependent on carbon as both locations have steam-generated power. Salt is available indigenously at both the Gulf Coast and southwestern Pennsylvania.

The basic vinyl chloride building blocks - acetylene and ethylene - may be produced from either bituminous coal or petroleum/natural gas fractions. On the Gulf Coast both acetylene and ethylene are used. However, planned expansions recently announced almost exclusively favor ethylene from the cracking of propane. In the northeastern United States, where bituminous coal is the source of carbon,

acetylene has been the primary intermediate and it is only recently that coking has been carried on at a large enough scale to make ethylene produced as a coking by-product a potential intermediate.

2. Carbide-Acetylene

For southwestern Pennsylvania, the process that uses only indigenous raw materials is based upon the use of acetylene from coal in combination with anhydrous hydrogen chloride at a high level of output to obtain purchased power at the lowest possible price. The process requires limestone, water, coke, bituminous coal and salt as the major raw materials, all of which are indigenously available in the Reesedale, Pennsylvania, area. The acetylene is manufactured from calcium carbide which, in turn, is produced electrothermically from coke and lime. The lime is produced from limestone and bituminous coal. The hydrogen chloride is produced from hydrogen and chlorine, each of which is produced electrochemically from brine derived from local salt wells. (See the Appendix for a more complete description of the carbide-acetylene process).

3. Ethylene ex Natural Gas

Recently announced expansions of vinyl chloride production are based on ethylene derived from natural gas. Liquified petroleum gas (LPG) consisting primarily of

propane removed from natural gas is thermally cracked to produce a mixture of ethylene, propylene and butylene. The ethylene is isolated as a pure material and the propylene and butylene are disposed as by-products. Salt is indigenously available on the Gulf Coast as natural brine and chlorine is produced electrochemically with caustic soda as a by-product. The chlorine is combined with the ethylene in a three-step process to yield vinyl chloride. First, ethylene and chlorine combine to form ethylene dichloride (EDC). Second, EDC is thermally cracked to form vinyl chloride monomer and anhydrous hydrogen chloride. Third, ethylene and anhydrous hydrogen chloride are combined, by oxychlorination, to form additional EDC. The three steps of the process are balanced so that vinyl chloride is the only product.

4. Acetylene and Ethylene ex Naphtha (Kureha Naphtha-Chlorine Process)

Naphtha is increasingly becoming significant as a "source of carbon" for petrochemicals in general and vinyl chloride in particular, especially in view of the possible availability of low cost imported naphtha as the result of increased import quotas. Complexes using imported naphtha are contemplated for the Gulf Coast. However, with cheap barge transport of naphtha, a southwestern Pennsylvania

location could be considered.

A brief description of the Kureha Naphtha Chlorine Process follows, but a more complete description is included in the Appendix, Section V. The partial combustion of naphtha with pure oxygen results in a mixture of acetylene and ethylene with other gases which remain essentially non-reactive in subsequent steps. The acetylene is removed from the mixture by combination with anhydrous hydrogen chloride to form vinyl chloride. The ethylene is next removed by combination with chlorine to form ethylene dichloride (EDC). Additional vinyl chloride is formed by thermally cracking the EDC with anhydrous hydrogen chloride produced as a by-product. The molar ratio of acetylene to ethylene is controlled in the partial oxidation step to result in the proper balance of each step so that no chlorine or hydrogen chloride is wasted and vinyl chloride is the only product. Here again, indigenous brine provides the salt.

The Kureha Process, it should be borne in mind, is not well established. Only limited process information is available in the United States and no information on the quality of the product or the application of the product for the manufacture of polyvinyl chloride. One commercial application of the process that started in Japan in 1964 accounts for some six per cent of Japan's vinyl chloride

output. However, it is reported that the process is being applied in India, Britain and the Soviet Union.

5. Comparison of Processes

In Table II-1 the raw material requirements and the product output of the principal polyvinyl chloride processes are compared at selected United States locations for chemical complexes producing 150,000 tons per year (430 tons per day) of PVC.

TABLE II-1

COMPARISON OF RAW MATERIAL REQUIREMENTS
AND PRODUCT OUTPUT OF 430 T/D POLYVINYL
CHLORIDE PLANTS

	<u>SW Penna.</u> <u>Coal and</u> <u>Chlorine</u>	<u>SW Penna.</u> <u>Naphtha &</u> <u>Chlorine</u>	<u>Gulf Coast</u> <u>Propane &</u> <u>Chlorine</u>
<u>RAW MATERIALS, T/D</u>			
Bituminous Coal	545	850	-
Coke	340	-	-
Naphtha	-	414	-
Propane	-	-	623
Salt	462	450	490
Natural Gas	-	-	131 (1)
Limestone	1,070	-	-
<u>POWER, KW</u>	125,000	60,000 (2)	66,300
<u>PRODUCTS, T/D</u>			
PVC	430	430	430
<u>BY-PRODUCTS, T/D</u>			
Caustic Soda	315	305	333
Limestone	160	-	-
Lime	450	-	-
Hydrogen	-	7.8	-
Propylene	-	-	111 (1)
Butadiene	-	-	26.5(1)

NOTES:

- (1) If propylene and butadiene are recovered as by-products the natural gas consumption must be increased by an equivalent thermal value.
- (2) 60,000 KW requires 576 T/D of bituminous coal.

III. ECONOMICS OF PRODUCING PVC IN SOUTHWESTERN PENNSYLVANIA

A. CARBIDE-ACETYLENE PROCESS

1. Capital Cost Estimate - Carbide-Acetylene

It is estimated that a chemical complex to manufacture 430 tons per day polyvinyl chloride, based on the carbide-acetylene route, will require a fixed capital expenditure of \$50.3 million and an additional working capital requirements of \$4.7 million for a total capital requirement of \$55 million.

The capital cost of a caustic-chlorine facility of sufficient size to provide the chlorine and hydrogen raw material requirements of the chemical complex is estimated to be \$12.2 million and includes \$1 million gross working capital.

The total capital cost for the remaining portions of the chemical complex for the manufacture of high purity polyvinyl chloride is estimated to be \$42.8 million for the facility and includes \$3.7 million for gross working capital. Funds are provided for limestone mining, calcination of lime, calcium carbide manufacture, acetylene generation and purification, anhydrous hydrogen chloride manufacture and purification, vinyl chloride monomer production and purification, and polyvinyl chloride production. Funds are also allocated for offsite facilities of the complex, e.g., land

and site development, boilers, water supply, cooling tower and water disposal.

Tables III-1 and III-2 summarize the capital cost requirements for the caustic-chlorine unit and for the balance of the project, respectively.

In preparing the estimates for the caustic-chlorine facility we have found that the area of greatest uncertainty lies in estimating the cost of drilling and fitting-out the brine wells. Well drilling is an uncertain art at best, and without detailed knowledge of the strata below, the best techniques for lowest cost are not likely to be used. For the second well, advantage will be taken of the knowledge gained in drilling the first well. Our estimate is based on actual experience in drilling and operating salt wells within three hundred miles of the site. Funds are also allocated for offsite facilities for the caustic-chlorine portion of the plant, e.g., land site development, boiler, water supply, cooling tower.

Estimates for the cost of the various manufacturing facilities were based upon available data on actual plant costs adjusted for size, location and time. Actual equipment costs were also utilized in developing the capital cost estimate. It is felt that the estimate should be accurate to plus or minus 10% over the next six months.

TABLE III-1

CAPITAL ESTIMATE
CAUSTIC-CHLORINE UNIT

PRODUCT - PVC
LOCATION - REESEDALÉ

<u>PLANT CAPACITY</u> - Operating 350 Days Per Year	<u>Tons Per Day</u>
Chlorine	285
Hydrogen	7.4
Caustic By-Product	315

FACILITIES

Land & Site Development (Allocated)	500,000
Roads, Railroads, Cooling Tower (Allocated)	1,500,000
Service Buildings (Allocated)	500,000
Brine Wells (2)	1,000,000
Production Plant:	
Brine Treatment	850,000
Cell House	2,500,000
Rectifiers & Electrical	1,100,000
Chlorine Handling	1,050,000
Caustic Evaporation	<u>2,200,000</u>

FIXED CAPITAL INVESTMENT	\$11,200,000
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<u>WORKING CAPITAL</u>	<u>1,000,000</u>
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TOTAL	<u><u>\$12,200,000</u></u>
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TABLE III-2

CAPITAL ESTIMATE*
CARBIDE-ACETYLENE UNITS

PRODUCT - PVC (150,500 Tons Per Year; 350 Operating Days
Per Year)

LOCATION - REESEDALE

<u>PLANT CAPACITIES</u>	<u>Tons Per Day</u>
Polyvinyl Chloride	430
Vinyl Chloride	450
Acetylene, 99.5% Minimum	190
Anhydrous Hydrogen Chloride	290
Calcium Carbide, 85% CaC ₂	575
Lime, 90% CaO	530
Limestone, 95% CaCO ₃ (5 days, 1 shift)	1,500
By-Product Limestone (less than 2" stone)	160
By-Product Lime from C ₂ H ₂	450

FACILITIES

Limestone Mine	\$ 1,540,000
Lime Plant	2,080,000
Calcium Carbide Plant	8,025,000
Acetylene Plant	3,285,000
Vinyl Chloride Plant	11,600,000
Polyvinyl Chloride Plant	9,170,000
Offsites (Allocated)	<u>3,400,000</u>

FIXED CAPITAL INVESTMENT \$39,100,000

WORKING CAPITAL 3,700,000

TOTAL \$42,800,000

* Exclusive of facilities for chlorine
and hydrogen.

2. Operating Cost Estimate - Carbide-Acetylene

An operating cost of \$159.41 per ton (eight cents per pound) was estimated for manufacture of 430 tons per day of polyvinyl chloride. The primary raw material cost elements in the operation include local bituminous coal readily available at \$5.50 per ton, and coke at \$10.50 per ton delivered. No credit was taken for revenues derived from the sale of by-product limestone, by-product lime or, by-product caustic soda, or spent sulfuric acid.

A power rate for the proposed polyvinyl chloride chemical complex was assumed at 4.0 mills per KWH. It is believed that this rate can be negotiated with the West Penn Power Company, based upon recent discussions. The rate would be dependent on a 125,000 KW minimum power load requirement for the vinyl chloride plant and the adjacent caustic-chlorine unit.

For the caustic-chlorine plant, costs for cell parts and anode renewal were based on Hooker Chemical Corporation's figures for its new plant in Louisiana. Salt well maintenance has been taken at \$280,000 per year to cover anticipated major repairs. Routine maintenance is only a fraction of the costs involved in the repairs due to rock shifts.

A cost breakdown for each phase of the operation

is set forth on the following pages. The general expense items included in each phase represents an estimate of the following costs: plant administration and supervision, maintenance labor and supplies, analytical laboratory, development, office staff, yard gang, miscellaneous supplies plant and labor overhead, industrial relations department, property and school taxes and insurance. The general expense item included in each phase was first estimated for the entire plant and was then allocated to the individual manufacturing operations proportional to the labor costs. The following is an estimate of the general expense items for the plant:

GENERAL EXPENSE ESTIMATE

<u>General Expense Labor</u>			Annual \$	Expense \$/T PVC
1.	Plant Administration	15 @ \$16,000	240,000	1.55
2.	Industrial Relations, Safety, Etc.	40 @ 6,000	240,000	1.55
3.	Laboratory, Control & Analytical	50 @ 8,000	400,000	2.59
4.	Plant Technical Services	25 @ 13,000	325,000	2.10
5.	Clerical, Accounting, Purchasing	70 @ 7,000	<u>490,000</u>	<u>3.16</u>
6.	SUB-TOTAL		1,695,000	10.94
7.	Maintenance Labor	80 @ 8,000	640,000	4.12
8.	Yard Gang Labor	70 @ 5,500	385,000	2.48
9.	Maintenance & Supervision	20 @ 10,000	<u>200,000</u>	<u>1.28</u>
10.	SUB-TOTAL			
	GENERAL EXPENSE LABOR		2,920,000	18.83

		Annual \$	Expense \$/T PVC
11.	Operating Supervision 32 @ \$8,000	256,000	1.65

General Expense Material

12.	Maintenance Materials - 100% of Maintenance Labor (Item 7 above)	640,000	4.13
13.	Other Materials - 50% of Non- Maintenance Labor (Item 6 above)	850,000	5.49

General Expense - Other Items

14.	Payroll Burdens, Vacation, Sick Leave, Social Security, Unemploy- ment Insurance, Etc. - 25% of total plant payroll	1,313,600	8.47
15.	Taxes, County, School and Property	850,000	5.49
16.	Insurance Premium	<u>195,000</u>	<u>1.26</u>
	TOTAL	\$7,024,600	\$45.32

Manufacturing costs at different levels of operation
are included for the polyvinyl chloride plant.

a. SUMMARY OF OPERATING COSTS BY MANUFACTURING SEGMENT
Basis: 430 Net Tons per Day Polyvinyl Chloride

Mining Cost	\$ 2.35/Ton Limestone
Lime Manufacture	10.22/Ton Lime, 90% Purity
Calcium Carbide	36.28/Ton 85% Calcium Carbide
Chlorine	57.31/Ton Chloride
Acetylene	146.48/Ton 99.5% Min. Purity
Monovinyl Chloride	118.24/Ton Pure Monomer
Polyvinyl Chloride	159.41/Ton Pure Polymer

b. SUMMARY OF MINING OPERATION COST ESTIMATE

Basis: 1,500 Net Tons per Day Limestone, Five Days
per Week Operation, One Shift per Day Only

	Unit Cost <u>\$/Ton</u>	Unit Cost <u>\$/Ton PVC</u>
Mining Materials, Miscellaneous (Drills, Explosives, Etc.)	0.60	1.44
Labor: 28 Men/Shift @ \$2.50/Hr.	0.37	0.89
Utilities	0.06	0.14
General Expense	0.93	2.23
Depreciation	<u>0.39</u>	<u>0.94</u>
Limestone Rock (Delivered)	\$2.35	\$5.64

c. SUMMARY OF LIME PRODUCTION OPERATING COST ESTIMATE

Basis: 530 Net Tons per Day, 90% Lime (CaO)

	Unit Cost <u>\$/Ton</u>	Unit Cost <u>\$/Ton PVC</u>
Materials:		
Limestone @ \$2.35/Ton	4.80	5.64
Coal-Bituminous @ \$5.50/Ton	<u>1.97</u>	<u>2.32</u>
	6.77	7.96
Labor - 12 Men/Shift @ \$2.50/Hr	0.45	0.53
Utilities:		
Power @ 4 Mills/KWH	0.05	0.06
General Expense	1.55	1.82
Depreciation	<u>1.40</u>	<u>1.65</u>
Manufactured Lime	\$10.22	\$12.02

d. SUMMARY OF CALCIUM CARBIDE OPERATING COST ESTIMATE

Basis: 545 Net Tons per Day; 85% CaC₂ at 95% Yield.

	Unit Cost \$/Ton	Unit Cost \$/Ton PVC
Materials:		
Lime, 90% CaO @ \$10.22/Ton	8.90	12.02
Coke, 87% C @ \$10.50/Ton	6.15	8.30
Coal-Anthracite@\$ 8.00/Ton	0.12	0.16
Pitch @ \$44.00/Ton	<u>0.16</u>	<u>0.22</u>
	15.33	20.70
Labor: 24 Men/Shift @ \$2.50/Hr.	0.88	1.18
Utilities: Power @ 4 Mills/KWH	12.04	16.25
General Expense	3.03	4.06
Depreciation	<u>5.00</u>	<u>6.75</u>
Calcium Carbide	\$36.28	\$48.94

e. SUMMARY OF CRUDE ACETYLENE MANUFACTURING COST ESTIMATE

Basis: 188 Net Tons per Day of 99.5% C₂H₂ @ 97% Yield

	Unit Cost \$/Ton	Unit Cost \$/Ton PVC
Materials:		
Calcium Carbide @ \$36.28/Ton	107.93	48.94
Labor: 16 Men/Shift @ \$2.75/Hr.	5.65	2.56
Utilities: Power, Steam, Water	0.56	0.25
General Expense	19.45	8.81
Depreciation	<u>2.28</u>	<u>1.03</u>
Crude Acetylene Gas	\$135.87	\$61.59

f. SUMMARY OF CAUSTIC-CHLORINE OPERATING COST ESTIMATE

Basis: 285 Net Tons per Day Chlorine
 315 Net Tons per Day Caustic Soda
 600 Net Index Tons per Day

	UNIT COST		
	<u>\$/Index Ton</u>	<u>\$/Ton Chlorine</u>	<u>\$/Ton PVC</u>
Materials:			
Salt	-	-	-
Sulphuric Acid @ \$25/Ton	0.36	0.76	0.49
Miscellaneous Chemicals	0.50	1.05	0.68
Coal @ \$5.50/Ton	3.22	6.76	4.39
Cell Renewal (by Hooker)	<u>3.83</u>	<u>8.04</u>	<u>5.21</u>
Materials Total	7.91	16.61	10.77
Labor: 10 Men/Shift @ \$3.20/Hr.	1.28	2.69	1.74
Electricity @ \$0.004/KWH	6.48	13.61	8.86
General Expense	4.41	9.26	5.99
Depreciation	5.65	11.87	7.70
Miscellaneous Chlorine Costs			
Royalty (by Hooker)	0.26	0.55	0.36
Salt Well Maintenance	<u>1.30</u>	<u>2.72</u>	<u>1.77</u>
TOTAL	27.29	57.31	37.20

g. SUMMARY OF ACETYLENE PURIFICATION OPERATING COST ESTIMATE

	<u>Unit Cost</u> <u>\$/Ton</u>	<u>Unit Cost</u> <u>\$/Ton PVC</u>
Materials:		
Crude Acetylene @ \$135.87/Ton	135.87	61.59
Sulphuric Acid, 60°Be.	0.04	0.02
50% Caustic Soda @ \$50/Ton	1.04	0.47
Chlorine @ \$57.86/Ton	0.28	0.13
Activated Carbon @ 20¢/Pound	<u>0.31</u>	<u>0.14</u>
	137.54	62.35
Labor: 12 Men @ \$2.75/Hr.	1.40	0.63
Utilities	- (1)	- (1)
General Expense	4.82	2.17
Depreciation	<u>2.72</u>	<u>1.23</u>
Pure Acetylene	146.48	66.38

h. SUMMARY OF HYDROGEN CHLORIDE OPERATING COST ESTIMATE

	<u>Unit Cost</u> <u>\$/Ton</u>	<u>Unit Cost</u> <u>\$/Ton PVC</u>
Materials:		
Chlorine @ \$57.31/Ton	57.31	37.20
Hydrogen (A By-Product From Chlorine Manufacture)	<u>-</u>	<u>-</u>
	57.31	37.20
Labor: 3 Men/Shift @ \$3.20/Hr.	0.79	0.53
Utilities	- (2)	- (2)
General Expense	<u>2.72</u>	<u>1.82</u>
Pure Hydrogen Chloride	60.82	39.55

(1) Utility cost included in cost of crude acetylene.

(2) Utility cost in cost of monovinyl chloride.

i. SUMMARY OF MONOVINYL CHLORIDE OPERATING COST ESTIMATE

Basis: 95% Yield - 450 Net Tons/Day

	Unit Cost <u>\$/Ton</u>	Unit Cost <u>\$/Ton PVC</u>
Materials:		
Acetylene, Purified @ \$146.74/Ton	64.20	66.38
Anhydrous Hydrogen Chloride @ \$60.82/Ton	38.25	39.55
Catalyst	5.59	5.78
50% Caustic Soda	0.66	0.68
Hydrochloric Acid - 22°Be.	<u>0.02</u>	<u>0.02</u>
	108.72	112.41
Labor: 15 Men/Shift @ \$3.20/Hr.	0.87	0.90
Utilities	1.31	1.35
General Expense	3.00	3.10
Depreciation	<u>4.34</u>	<u>4.49</u>
Monovinyl Chloride Monomer	118.24	122.25

j. SUMMARY OF POLYVINYL CHLORIDE OPERATING COST ESTIMATE

Basis: 96% Yield - 430 Net Tons Per Day

	Unit Cost <u>\$/Ton</u>	Unit Cost <u>\$/Ton PVC</u>
Materials:		
Pure Monomer @ \$119.87/Ton	122.25	122.25
Miscellaneous Chemicals, Catalyst and Supplies	6.59	6.59
Labor: 75 Men/Shift @ \$3.20/Hr	4.45	4.45
Utilities: Steam, Power, Water	4.87	4.87
General Expense	15.32	15.32
Depreciation	<u>5.93</u>	<u>5.93</u>
Polyvinyl Chloride Resin	159.41	159.41

k. CONSOLIDATED OPERATING COST ESTIMATE - PVC FROM
CARBIDE-ACETYLENE, REESEDALÉ, PENNSYLVANIA.

\$/Ton PVC

Materials:

Bituminous Coal	6.71	
Coke	8.30	
Caustic-Chlorine		
Cell Renewal	5.21	
Catalyst, VCM	5.78	
Catalyst, PVC	6.59	
Miscellaneous	<u>4.48</u>	37.07

<u>Labor</u>	13.41	
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<u>Utilities</u>	31.77	
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Miscellaneous

Caustic Chlorine Expenses	2.13	
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<u>General Expense</u>	<u>45.32</u>	129.68
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<u>Depreciation</u>	<u>29.73</u>	
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TOTAL		<u><u>159.41</u></u>
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3. Project Payout and Cash Flow - Carbide-Acetylene

The total capital investment for the proposed carbide acetylene complex has been estimated at \$55 million. The direct operating cost for manufacture of polyvinyl chloride (PVC) has been estimated to be 7.97 cents per pound PVC based upon an output of 150,500 tons (300 million pounds) per year. The cost includes a depreciation charge of 1.63 cents per pound based upon \$50.3 million of depreciable assets.

The selling and administrative expense for the operation were assumed to be 7-1/2 per cent of gross sales when operating at full capacity. No credit was taken for any possible sales of by-product lime or limestone. A freight charge of one-quarter cent per pound of PVC was assumed.

An average selling price of 10.5 cents per pound was assumed for the polymer and an average unit revenue of \$40 per ton of caustic soda after distribution and transportation costs.

The operating income before tax for the project at operating levels of 40, 70 and 100 per cent of capacity is shown in Table III-3.

TABLE III-3INCOME VERSUS OPERATING RATE - CARBIDE-ACETYLENE

PRODUCT - PVC

LOCATION - REESEDALE

	<u>Plant Operating, % Capacity</u>		
	<u>40</u>	<u>70</u>	<u>100</u>
Output, Annual Tons PVC	60,200	105,350	150,500
Output, Annual Tons Caustic Soda	44,100	77,175	110,250
<u>Revenue, \$ Million</u>			
PVC Sales @ 10½/Lb.	12,642	22,124	31,605
Caustic Soda @ \$40/T	<u>1,764</u>	<u>3,087</u>	<u>4,410</u>
TOTAL	14,406	25,211	36,015
<u>Cost, \$ Million</u>			
Manufacturing @ \$129.68/Ton	7,807	13,662	19,517
Selling & Administrative Expense @ 7½% Sales of 100%	2,701	2,701	2,701
Freight @ \$5/Ton PVC	<u>0,301</u>	<u>0,527</u>	<u>0,753</u>
TOTAL	10,809	16,890	22,971
<u>Gross Income, \$ Million</u>	3,597	8,321	13,044
<u>Depreciation, \$ Million</u>	5,051	5,051	5,051
<u>Income Before Tax, \$ Million</u>	(1,454)	3,270	7,993

The "break-even" point, exclusive of financing costs, is 75,000 net tons per year or 50 per cent of design capacity. The "break-even" point was determined by including the fixed charge of \$5,051,000 depreciation and \$2,701,000 sales and administration expense, plus the variable operating cost of 6.57 cents per pound PVC and 0.5 cents per pound freight charges and estimating the annual output at an average unit price of 10.5 cents per pound of PVC and \$40 per ton caustic soda so as to have annual charges equal to annual sales. The annual output for a "break-even" situation under these conditions is 75,000 net tons PVC or 50 per cent of plant capacity. The annual depreciation charge was based on an assumed ten-year life, which is the typical period for a chemical project, especially a synthetic resin unit.

As can be seen from the development of income before tax at various capacity levels, the operation is fairly stable as all costs including depreciation are covered down to 50 per cent of capacity. It may be said that the probability of a profitable operation is about 50 to 65 per cent. It should be emphasized, however, that the above analysis has assumed that unit costs of polymer raw materials, utilities and labor remain constant and that the estimated sales price can be realized for the projected market volumes.

In Table III-4 that follows, payout time at various

operating levels is shown for two different financing methods. In each case, the payout time is defined as the ratio of the total capital (\$55 million) to the total annual cash flow. Two methods of financing are considered:

CASE A - Equity financing for 100 per cent of project expenditures.

CASE B - A 50/50 ratio of equity financing and long-term five per cent interest-bearing loans.

The effect of introducing debt participation is made on the basis that to justify debt participation in the capital budgeting, debt repayment is considered an annual fixed charge. Debt participation therefore adds interest to the annual operating charges and required fixed payment into the sinking fund from income after taxes and thus raises the "break-even" operating rate from 50 per cent of capacity for no debt participation to 87 per cent for 50/50 debt equity. The probability for profitable operation is thus reduced by debt participation. However, the financial attractiveness of the venture remains fundamentally the same with the payout time at 6.28 years for 100 per cent equity compared to 6.78 years for the 50 per cent equity case. On the conservative basis that at the end of the complex's ten-year economic life no capital can be recovered by its sale, a payout time of 6.28 years corresponds to an

interest rate of 9.5 per cent for a ten-year term and a payout time of 6.78 years to an interest rate of 8.79 per cent for a ten-year term.

The basis of this financial analysis assumes that the project is undertaken by an established firm with capital reserves and conservative financial practices. It is this type of firm which would possess the marketing capability to achieve the level of operating rate necessary for profitability.

TABLE III-4

PAYOUT TIME VERSUS OPERATING RATE
CARBIDE-ACETYLENE

PRODUCT - PVC
LOCATION - REESEDALE

<u>CASE A, 100% Equity</u>	<u>Plant Output, % Capacity</u>		
	* \$ Thousands		
	<u>40</u>	<u>70</u>	<u>100</u>
Income Before Tax*	(1,454)	3,270	7,993
Federal & State Income Taxes*	(785)	1,766	4,316
Net Income After Taxes*	(669)	1,504	3,677
Cash Flow*	4,382	6,555	8,720
Payout Time, Years	12.5	8.4	6.28

<u>CASE B, 50% Equity, 50% Debt</u>	<u>Plant Output, % Capacity</u>		
	* \$ Thousands		
	<u>80</u>	<u>87</u>	<u>100</u>
<u>Revenue*</u>	28,812	31,333	36,015
<u>Cost*</u>			
Manufacturing Selling Exp.	18,916	20,336	22,971
Administrative Expense, Freight			
Interest @ 5 per cent	1,375	1,375	1,375
Depreciation	5,051	5,051	5,051
Income Before Tax*	3,470	4,571	6,618
Income Tax*	1,874	2,478	3,574
Income After Tax*	1,596	2,103	3,044
Sinking Fund Deposit @ 5 per cent Interest, for ten years*	2,187	2,187	2,187
Net Income After Tax*	(591)	(84)	857
Cash Flow*	6,647	7,154	8,095
Payout Time, Years	8.27	7.7	6.78

B. KUREHA NAPHTHA CHLORINE PROCESS

1. Capital Cost Estimate - Kureha Process

It is estimated that a chemical complex to manufacture 430 tons per day polyvinyl chloride will require a fixed capital expenditure of \$40.57 million and an additional working capital requirement of \$3.5 million for a total capital requirement of \$44.07 million.

The capital cost of a caustic chlorine facility of sufficient size to provide the chlorine raw material requirement of the chemical complex is estimated to be \$12.2 million and includes \$1 million gross working capital. The total capital cost for the remaining portions of the chemical complex for the manufacture of polyvinyl chloride is estimated to be \$31.87 million and includes \$3.7 million for gross working capital. Funds are provided for air separation, partial oxidation of naphtha, vinyl chloride monomer manufacture and purification and polyvinyl chloride manufacture.

Funds are also allocated for offsite facilities of the complex: land and site development, boilers, water supply, cooling tower and waste disposal.

TABLE III-5

CAPITAL ESTIMATE SUMMARY - KUREHA PROCESS

PRODUCT - PVC
LOCATION - REESEDALE
350 OPERATING DAYS PER YEAR

Basis:

Caustic Chlorine Plant	277 Tons Per Day Chlorine
	305 Tons Per Day Caustic Soda
Vinyl Chloride Plant	450 Tons Per Day Vinyl Chloride Monomer
PVC Plant	430 Tons Per Day PVC

Caustic-Chlorine Plant (Includes Allocated Offsites and Brine Wells)	\$11.20 Million
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Vinyl Chloride Monomer Plant (Includes Allocated Offsites)	17.30
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Poly Vinyl Chloride Plant (Includes Allocated Offsites)	<u>12.07</u>
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TOTAL FIXED CAPITAL	\$40.57 Million
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TOTAL WORKING CAPITAL	<u>3.50</u>
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TOTAL CAPITAL	\$44.07 Million
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2. Operating Cost Estimate - Kureha Process

An operating cost of \$162.60 per ton was estimated for the manufacture of 430 tons per day of polyvinyl chloride. The primary raw materials required are petroleum naphtha and bituminous coal. Petroleum naphtha is available on the Gulf Coast at 8 cents per gallon and can be shipped by 1,300-ton barge to southwestern Pennsylvania for an estimated \$5.00 per ton (subject to negotiation).

In winter, when the river is unnavigable, the naphtha can be shipped by rail for \$23.40 per ton. It is estimated, for the purpose of this report, that for eleven months of the year naphtha can be shipped by barge and that rail shipment would be used for the remaining month. This would give an average cost of shipping the naphtha at \$6.50 per ton.

The bituminous coal can be delivered to the plant site at \$5.50 per ton. Power, the next most significant cost element, is charged in the operating cost estimate at a rate of 5.5 mills per KWH, based on West Penn Power schedules for a 60,000 KW load purchased as 50 per cent firm power and 50 per cent interruptible power. No revenues have been assumed from the by-product hydrogen.

For the caustic-chlorine plant, costs for cell parts and anode renewal parts were based on Hooker Chemical

Corporation's figures for its new plant in Louisiana. Salt well maintenance has been taken at \$280,000 per year to cover major repairs.

General expense items - plant administration and supervision, maintenance labor and supplies, plant and labor overhead, industrial relations department, property and school taxes, and insurance - were estimated for the entire complex and were allocated to the individual manufacturing units proportional to the labor costs.

a. SUMMARY OF CAUSTIC-CHLORINE OPERATING COST ESTIMATE

Basis: 277 Tons Per Day Chlorine
 305 Tons Per Day Caustic Soda
 582 Index Tons Per Day

<u>Materials:</u>	<u>Unit Cost</u> <u>\$/Ton Chlorine</u>	<u>Unit Cost</u> <u>\$/Ton PVC</u>
Salt	-	-
Sulfuric Acid	0.76	0.48
Miscellaneous	1.05	0.67
Coal @ \$5.50/Ton	6.76	4.30
Cell Maintenance	<u>8.04</u>	<u>5.11</u>
	16.61	10.56
Labor: 10 Men/Shift @ \$3.20/Hour	2.69	1.71
Power @ \$.0055/KWH	18.71	11.90
Miscellaneous Expense	3.78	2.40
General Expense	<u>9.81</u>	<u>6.24</u>
	51.60	32.81
Depreciation	<u>11.87</u>	<u>7.55</u>
	63.47	40.36

b. SUMMARY OF OPERATING COST ESTIMATE OF COMBINED NAPHTHA
CRACKING AND VINYL CHLORIDE MONOMER MANUFACTURE

Basis: 450 Net Tons Per Day of Vinyl Chloride

Materials:	Unit Cost <u>\$/Ton</u>	Unit Cost <u>\$/Ton PVC</u>
Naphtha 0.930 Tons/Ton VCM @ 5.52 Pounds/Gallon, in- cluding estimated freight cost from Gulf Coast to Southwestern Pennsylvania	33.01	34.15
Chlorine 0.615 Tons/Ton VCM @ \$63.47/Ton	39.03	40.36
Miscellaneous Chemicals @ .45¢/Pound VCM	9.00	9.30
Coal 1.02 Pound Coal/Pound VCM @ \$5.50/Ton	<u>5.63</u> 86.67	<u>5.83</u> 89.64
Labor: 18 Men/Shift @ \$3.20/Hr.	3.07	3.17
Utilities: 0.5 KWH/Pound VCM @ \$.0055/KWH	5.50	5.69
General Expense	<u>11.20</u> 106.44	<u>11.58</u> 110.08
Depreciation	<u>10.37</u> 116.81	<u>10.72</u> 120.80

c. SUMMARY OF POLYVINYL CHLORIDE OPERATING COST ESTIMATE

Basis: 96% Yield - 430 Net Tons Per Day

Materials:	Unit Cost \$/Ton PVC
Pure Monomer @ \$116.81/Ton	120.80
Miscellaneous Chemicals, Catalyst and Supplies	<u>6.59</u>
	127.39
Labor: 75 Men/Shift @ \$3.20/Hour	4.45
Power	2.91
Water and Steam	5.67
General Expense	<u>16.24</u>
	156.66
Depreciation	<u>5.96</u>
TOTAL	162.62

d. POLYVINYL CHLORIDE CONSOLIDATED OPERATING COST ESTIMATE

Naphtha-Acetylene Ethylene - Reesedale

Materials:	Unit Cost \$/Ton PVC
Bituminous Coal	10.12
Naphtha	34.15
Caustic-Chlorine Cell Renewal	5.11
Chemicals and Catalysts	<u>17.05</u>
	66.43
Labor	9.33
Utilities	26.17
Miscellaneous Caustic-Chlorine Expense	2.40
General Expense	<u>34.16</u>
	138.41
Depreciation	<u>24.21</u>
TOTAL	162.62

3. Project Payout and Cash Flow - Kureha Process

The total capital investment for the proposed complex has been estimated at \$44.07 million. The direct operating cost for the manufacture of PVC has been estimated at 8.13 cents per pound PVC based upon an output of 150,000 tons per year. The cost includes a depreciation charge of 1.21 cents per pound PVC based on \$40.57 million of depreciable assets.

An average selling price of 10.5 cents per pound for PVC has been assumed, as previously discussed in this report. The net revenue from the sale of the by-product caustic soda as the 50 per cent liquid was based on a net average value of \$40 per ton on a 100 per cent basis for the entire plant output, after transportation and distribution costs. Selling and administrative expense for the operation were assumed to be 7-1/2 per cent of gross sales when operating at full capacity. A freight charge of one-quarter cent per pound of PVC was assumed.

The payout time for the project at operating levels 40, 70 and 100 per cent of capacity is shown in Table III-6.

The "break-even" operating rate is 75,000 net tons per year, or 50 per cent of design capacity. The payout time at 100 per cent operating rate is 5.82 years. On the basis that no capital is recovered after the ten-year economic

life of the complex, the 5.82 year payout time corresponds to an interest rate of 11.4 per cent for a ten-year term.

TABLE III-6

PAYOUT TIME VS OPERATING RATE - KUREHA PROCESS

PRODUCT - PVC

LOCATION - REESEDALE

	<u>Plant Operation, % Capacity</u>		
	<u>* \$ Thousands</u>		
	<u>40</u>	<u>70</u>	<u>100</u>
Output			
Annual Tons PVC	60,200	105,350	150,500
Annual Tons Caustic Soda	44,100	77,175	110,250
Revenue*			
PVC Sales @ 10½¢/Lb.	12,642	22,124	31,605
Caustic Soda	<u>1,764</u>	<u>3,087</u>	<u>4,410</u>
TOTAL	14,406	25,211	36,015
Cost*			
Manufacturing @ \$138.41 Per Ton PVC	8,335	14,587	20,838
Selling & Administrative Expense @ 7½¢ Sales of 100%	2,701	2,701	2,701
Freight @ \$5/Ton PVC	<u>301</u>	<u>527</u>	<u>753</u>
TOTAL	11,337	17,815	24,292
Gross Income*	3,069	7,396	11,723
Depreciation*	4,057	4,057	4,057
Net Income Before Tax*	(988)	3,339	7,666
Net Income After Tax*	(454)	1,536	3,526
Depreciation*	4,057	4,057	4,057
Cash Flow*	3,603	5,593	7,583
Payout Time, Years	12.3	7.88	5.82

C. COST COMPARISON OF "GRASS-ROOTS" PVC PLANTS

The economics of four different PVC plants are analyzed and the results are listed in Table III-7. These plants are distinguished by location and employ manufacturing processes described in the preceding paragraphs.

The two Gulf Coast plants shown in the table are based on the premise that the vinyl chloride will be shipped up to a polymer plant in the Northeast. The economics for the Gulf Coast plants include the investment and operating costs of a "grass-roots" vinyl chloride plant located on the Gulf Coast and a polymer plant located in the Northeast.

The naphtha-based petrochemical process is the Kureha Naphtha-Chlorine Process described in the Appendix. The propane-based petrochemical process is included to provide a means of assessing the competitive position of a Reesedale PVC plant, since the Gulf Coast-based propane process accounts for the bulk of the PVC presently being produced in this country and is also the process on which current vinyl chloride plant expansions are based.

The naphtha-based process is evaluated at a Gulf Coast location to determine the soundness of the Reesedale site for this process.

From the table it can be seen that economically the best PVC process for southwestern Pennsylvania is the

petrochemical naphtha process. Although the naphtha process has a slightly higher (one per cent) operating cost than the carbide process, its lower investment cost by 20 per cent makes it more attractive. The total investment for a plant of this type is \$44 million as compared to \$55 million for the carbide-acetylene process. The total investment figures represent the sum of the fixed investment and the working capital. The cost of manufacturing PVC is essentially the same for both processes at Reesedale: naphtha process - \$187.56 per ton; carbide-acetylene - \$185.23 per ton. (The propane process located on the Gulf Coast also produces PVC at an equivalent manufacturing cost - \$187.39).

The manufacturing cost includes transportation charges. The transportation cost of \$21.40 per ton PVC shown on Table III-7 - propane-petrochemical process - consists of a freight cost of \$16.40 to ship the vinyl chloride necessary to produce one ton of PVC from the Gulf Coast to a polymer plant located in the Northeast, plus a freight charge of \$5.00 per ton for PVC shipped from the polymer plant to the consumer. These two freight charges are combined to obtain the total freight charges necessary to bring the PVC to the consumer.

Listed under materials are carbon source and fuel costs. The cost of the carbon source shows the cost of the

various carbon supplying raw materials, such as naphtha, propane, and coke. The high cost of the carbon source for the naphtha process at Reesedale - \$34.15 per ton PVC versus only \$8.30 per ton for carbide-acetylene process is offset by other factors, such as lower costs for labor, power, general expenses and depreciation.

Although the payout time for the petrochemical propane-based process on the Gulf Coast would be slightly more attractive because of its lower investment - \$42 million versus \$44 million - the Kureha Naphtha Chlorine Process is competitive.

TABLE III-7

OPERATING AND INVESTMENT COST COMPARISON
OF "GRASS-ROOTS" PVC PLANTS

Basis: 150,500 Net Tons Per Year PVC Resin

	Southwest Pennsylvania		Gulf Coast Petrochemical		Gulf Coast Petrochemical		Southwest Pennsylvania Petrochemical	
	Coal		Naphtha		Propane		Naphtha	
Carbon Source	Bituminous Coal & Coke		Natural Gas		Natural Gas		Bituminous Coal	
Fuel	Artificial Brine at Site		Natural Brine at Site		Natural Brine at Site		Artificial Brine at Site	
Salt Source	Carbide- Acetylene		Acetylene- Ethylene		Ethylene		Acetylene- Ethylene	
Process	55	44.07	42	44.07	270.96	284.32	44.07	284.32
INVESTMENT	354.83	284.32						
Total, \$ Million \$/Ton PVC								

MANUFACTURING COST,
\$/TON PVC

Materials

Carbon Source	8.30 (2)	32.69 (1)	24.00 (3)	34.15 (1)
Fuel	6.71 (4)	8.40 (5)	10.43 (5)	10.12 (4)
All Materials	37.07	53.74	49.55	60.44

(Continued next page)

TABLE III-7 (Continued)

	Southwest Pennsylvania Coal	Gulf Coast Petrochemical	Gulf Coast Petrochemical	Southwest Pennsylvania Petrochemical
<u>Labor</u>	13.41	9.33	8.43	9.33
Utilities	31.77 (7)	31.72 (8)	31.53 (8)	26.17 (6)
Misc. Chlorine Expense	2.13	2.40	2.63	2.40
General Expense	45.32	34.08	30.72	34.08
Depreciation	32.59	26.20	25.19	26.20
Freight	5.00 (9)	21.40 (10)	21.40 (10)	5.00 (9)
Selling & Administrative Expense 7% of Net Sales				
Revenue PVC @ 10¢/Lb. & Caustic @ \$40/Ton	17.94	17.94	17.94	17.94
Total Cost of Sales \$/Ton PVC	185.23	199.92	187.39	187.56
Notes: (1) Naphtha @ \$35.50/T (8¢/gal.FOB Gulf Coast + \$6.50/T average freight to southwestern Pennsylvania)				
(2) Coke @ \$10.50/Ton				
(3) Propane purchased @ \$0.035/gal. and by-product burned as fuel				
(4) Bituminous coal @ \$5.50/Ton				
(5) Natural gas @ \$0.25/MCF				
(6) Power @ 5.5 mills/KWH (50% firm and 50% interruptible)				
(7) Power @ 4 mills/KWH				
(8) Power @ 7 mills/KWH				
(9) PVC freight charge to consumer @ 0.25¢/Lb.				
(10) Total VC and PVC freight charges @ 1.07¢/Lb.				

NOTES to Table III-7 continued.

- (6) Power @ 5.5 mills/KWH (50% firm and 50% interruptible)
- (7) Power @ 4 mills/KWH.
- (8) Power @ 7 mills/KWH.
- (9) PVC freight charge to consumer @ 0.25¢/lb.
- (10) Total VC and PVC freight charges @ 1.07¢/lb.

IV. CONCLUSIONS

A. GROWTH RATE OF PVC

Consumption of polyvinyl chloride plastic reached two billion pounds in 1965, maintaining its annual rate of growth in excess of 15 per cent per year. The growth of PVC consumption will continue and will be sustained by a continuance of the trend of aggressive marketing and lower prices. The average value of PVC consumed is expected to reach 11-1/2 cents per pound by 1970 compared to 14 cents per pound in 1964. Reduced cost of manufacture of vinyl chloride monomer resulting from the use of new process technology and large scale high efficiency producing units will provide the primary basis for continuing expansion of the PVC market.

Currently the facilities producing vinyl chloride monomer are operating very close to capacity. Announced expansions scheduled for completion by 1968, however, will bring total United States vinyl chloride capacity to almost four billion pounds per year; market expansion of PVC would have to average over 25 per cent per year for the next three years to keep pace with the additional output. Large increments added to the nation's vinyl chloride monomer producing capacity will result in periods of over-capacity which will maintain the pressure for lower prices and which may result

in the shutdown of some older, less efficient producing units. Firms planning expansion of vinyl chloride either expect the annual market growth rate to reach 25 per cent from 15 per cent, or that up to 500 million pounds per year of existing production capacity will be shut down by 1968. (Of course, the possibility exists that productive capacity may rise more slowly than is indicated by currently announced expansion plans due to either rescheduling or, as in the case of American - Skelly Oil, the firm may cancel its expansion.)

B. POTENTIAL CLIENTS FOR REESEDALE

Following the trend set by the recent entries into the vinyl chloride monomer and polyvinyl chloride (PVC) field, the establishment of a "grass-roots" chemical complex for the manufacture of PVC at Reesedale would most likely be undertaken as a joint venture.

The manufacture of PVC is being undertaken more and more by vertically integrated producers. Only 12 per cent of current PVC capacity is held by firms who do not manufacture vinyl chloride monomer. Of the remaining 88 per cent of PVC output which is manufactured by firms producing vinyl chloride, the trend has been toward ventures being undertaken by manufacturers who are also basic in the petroleum and/or natural gas source of carbon. Examples of firms

which are, or have the potential to be, basic in the raw materials for vinyl chloride are: Monsanto (Lion Oil); Stauffer-Continental Oil; Stauffer-Richfield Oil; American Can-Skelly Oil; Tenneco (Cary Chemical); and Allied Chemical (Union Texas Oil). Many of the PVC producers are further integrated to manufacture finished and semi-finished mechanical goods of PVC, such as bottles, sheet, rod, tube, pipe and extrusions. With control of the cost and quality from raw material source to the consumer, these producers are poised for broad expansion of the PVC market.

Firms producing vinyl chloride and PVC which do not have basic raw material positions with respect to petroleum carbon sources - such as Dow and Union Carbide - are actively seeking to obtain imported naphtha, either by free trade zones or through increased import quotas, and thereby become competitive with the more fully integrated producers.

For maximum profitability, potential members of a jointventure to establish a "grass-roots" chemical complex at Reesedale should have basic positions in one or more of the following areas: bituminous coal mining, petroleum production and refining, marketing capability in bulk plastics and capital resources.

C. GEOGRAPHICAL ADVANTAGES OF REESEDAL

The Reesedale site in southwestern Pennsylvania has unique plant location characteristics. It is 60 miles northeast from Pittsburgh on the navigable portion of the Allegheny River which is a part of the inland waterway system of the continental United States. In addition, the area is served by the Pittsburgh and Shawmut Railroad and the proposed Interstate Highway 80 which will pass 25 miles due north of Reesedale.

The river will enable low cost barge shipments of bulk raw material and products, such as caustic soda. The railroad will facilitate inbound shipment of bituminous coal and coke, also shipment of product polyvinyl chloride. The highway and railroad will facilitate the shipment of product polyvinyl chloride.

The Reesedale site is close to the heavy concentrations of plastic-forming and fabrication industry near the metropolitan areas of northeastern United States - such as Cleveland, Philadelphia and New York.

Finally, a factor of major importance in favoring the establishment of a chemical industry in Reesedale is that it is located in a region of mineral wealth. There is the probability of indigenous low cost limestone and salt. More important, Reesedale is in the western Pennsylvania

soft coal region which can provide low cost coke and low cost energy for heating and electric power. West Penn Power, which serves Reesedale, currently provides power for loads above 5,000 KW at 4.6 to 5.3 mills per KWH for interruptible power and 6.5 to 7 mills per KWH for firm power. For loads above 100,000 KW, however, discussions with West Penn Power indicate that power would probably be available at 4.0 mills per KWH on an "over-the-fence" basis.

For products such as polyvinyl chloride and caustic soda, the combination of low cost transportation facilities, access to the major consumers, cheap power and low cost source of carbon are an absolute necessity.

D. THE PETROCHEMICAL ROUTE TO PVC IN SOUTHWESTERN PENNSYLVANIA

The geographical advantages of Reesedale would probably serve the carbide-acetylene route with its greatest opportunity to be competitive in the PVC derby. Attractive cost factors such as indigenous raw materials, low cost transportation and power, and access to the major consuming market combine to make the carbide-acetylene route competitive. But the converse is questionable, that is, whether Reesedale would be best served by the carbide-acetylene route. While the carbide-acetylene process established PVC as a post-war growth product, cost reductions which were

necessary to achieve the current expansion were accomplished only with new processes based on petrochemical technology. Lower investment and labor costs coupled with higher depletion allowances propelled these new processes to dominate the supply of PVC in just ten years.

Reesedale - southwestern Pennsylvania - might best be served by combining its geographical advantages with a petrochemical process to produce PVC. Reesedale's probable indigenous salt, and its already competitive power and heating fuel costs, combined with a lower investment and competitive labor content process and aided by low cost river barge transportation of the petroleum or natural gas liquid raw material shows the economic promise necessary to place a PVC chemical complex in southwestern Pennsylvania.

In selecting a petrochemical route to PVC for Reesedale, the potential to remain profitable despite the prospect of a continuing trend of price reduction is another important factor. The use of straight ethylene from either the cracking of naphtha or of propane (LPG) relies on the utilization of by-product olefins - propylene and butadiene - for future profit potential. While this approach is more exciting from technical and development standpoints, it does not possess the degree of certainty for southwestern Pennsylvania that would be obtained by an approach which does not rely on

by-product utilization.

A petrochemical process for southwestern Pennsylvania with operating and investment costs competitive with Gulf Coast chemical complexes, the Kureha Process, employs acetylene and ethylene obtained from petroleum naphtha. Integrated operation in southwestern Pennsylvania would supplant the high cost transportation of the semi-finished material, vinyl chloride, with the inexpensive barge shipment of raw material naphtha. In addition, the Kureha Process does not require sale of by-products for profitability. Further, the Kureha Process is competitive in southwestern Pennsylvania using power at existing rates. If the market growth of PVC proves to be adequate, an expansion of plant size by two-thirds will increase the power load from 60,000 KW to 100,000 KW. At this load the power rate is expected to drop from 5.5 mills per KWH to 4.0 mills. The overall operating cost would drop $3\frac{1}{2}$ to 4 percent based on reduction in the power cost alone. The advantage of the 4 mill power rate might also be achieved if the plant using the Kureha Process were combined with another plant that would lift the total load to more than 100,000 KW.

The advantages of the Kureha Process, together with the advantages of southwestern Pennsylvania: low cost power and

fuel, probable availability if indigenous salt, and central location with regard to market, combine to make a chemical complex for the production of PVC from naphtha at Reesedale (southwestern Pennsylvania) competitive with a high degree of certainty.

V. APPENDIX

A. PROJECT DESCRIPTION OF A CARBIDE ACETYLENE PVC PLANT AT REESEDAL

To manufacture 300 million pounds per year of polyvinyl chloride at the proposed Reesedale site using the carbide acetylene route would entail mining and calcining of limestone rock, production of calcium carbide from lime and coke in an electric furnace, production of anhydrous hydrogen chloride with hydrogen and chlorine from a caustic-chlorine plant, generation of acetylene by the dry process from carbide, reaction of purified acetylene with anhydrous hydrogen chloride to form monovinyl chloride with subsequent polymerization of the monomer to polyvinyl chloride resin.

1. Limestone Mining

The purchase of limestone was considered from the Kaylor mine about 20 miles northeast of Reesedale at East Brady, Pa. The Kaylor rock could be delivered for an estimated \$2.50 to \$3.00 per ton, which is cheaper than purchase of Michigan and Ohio limestone on a delivered basis.

The local limestone is suitable for conversion to calcium carbide and acetylene. A new mining operation at a suitable outcropping of the Vanport formation above the river exists at a distance of about two miles west of the Reesedale site. Mining would be conducted through entries into the strata from which rooms with cross entries are

driven leaving suitable pillars for roof support. The strata at this location are up to 25 feet thick according to B. J. O'Neill, Jr. in Bulletin MSO, Penna. Geo. Survey 1964 - "Limestone and Dolomites of Pennsylvania."

The mine is assumed to operate on the day shift only, five days a week. The mine work schedule is divided into consecutive phases that would be conducted independently as a large number of working faces become available. In a given room, first the ceiling is "scaled", i.e., the roof removed of all loose broken stone. Loose stone from "scaling" is cleared by a bulldozer and then is loaded into a truck for transfer out of the mine. A heading that has been scaled is drilled next by a truck-mounted, jumbo drilling rig. Blasting follows drilling and the broken stone is loaded into trucks by a payloader. Output is attained by the use of heavy trackless equipment.

Compressed air and pressure water are furnished for the jumbo drilling rig. Deep well sump pumps are provided for removal of drainage water. The air compressors and the water pump are electric motor-driven. Trucks and bulldozers are diesel-powered. Suitable ventilation would be installed. Broken stone is transferred from the mine to the lime section of the acetylene plant by truck.

2. Limestone Rock Preparation

Limestone containing approximately 95 per cent calcium carbonate (CaCO_3) is delivered to the plant by truck at an average rate of 1500 tons per day, five days per week. The limestone is transferred by conveyor from the ore receiving area to a primary crusher where the rock is reduced to six inches or less. After screening, any oversize is recycled to the crusher via an oversize conveyor. A belt conveyor transfers the six-inch stone to a secondary crusher where stone size is reduced to two inches or less. Oversize, greater than two-inch stone, is removed by a double screen and recycled to the secondary crusher via a belt conveyor. The two-inch size limestone is then stored in a bin from where it is fed to the kiln feed hopper by weighing conveyor at a rate of 45 tons per hour. Stone less than two inches in size is held for marketing to agricultural and other users. A stone loss of 15 per cent was assumed. A uniform stone is required to attain a uniform burning rate in the kilns.

Bituminous coal, received by truck or rail, is reduced to less than one-half inch in a pulverizer. Oversize is removed by a vibrating screen and recycled to the pulverizer. The crushed coal is transferred by belt conveyor to a storage bin from where it is carried to the kiln feed

hopper by a weighing conveyor at a rate of eight tons per hour. Sixteen tons of coal per hour at 384 tons per day are consumed by the two kilns in the calcination operation.

3. Rotary Kiln Operation - Lime Manufacture

Two kilns operating in parallel produce lime with about a 90 per cent calcium oxide (CaO) content at a rate of 530 tons per day. The kilns are lined with refractory brick 9-1/2 to 10 inches thick. The burning zone in each kiln is 12 to 13 feet. The refractory bricks in the burning zone area consist of 60 to 65 per cent alumina and about 40 per cent in the remaining area.

The temperature of the burning zone is about 2375°F. At the rear of each kiln an inducted draught fan draws the dust and gases through dust chambers. The gases pass through the limestone bed on the preheater, increasing the temperature of the stone to about 1100°F. The waste gases then pass through a cyclone where the remaining dust is collected and finally to the chimney stack where the gas temperature is about 350°F.

The lime leaving the kiln passes through a Fuller cooler traveling over reciprocating stepped gates through which cold air is being heated.

Lime from the kiln is discharged to a conveyor with cooling and is then screened to remove all minus 1/8 inch

material. The remaining lime is bin-stored for later use in carbide manufacture. The minus 1/8 inch lime is stored for marketing to fertilizer, metallurgical and other users.

4. Calcium Carbide Manufacture

Coke at 87 per cent purity is received by rail or barge from local by-product and beehive oven operators and stored in an outdoor storage pile. The coke is transferred via conveyor to a primary crusher where it is reduced to four-inch size and then to a secondary crusher where it is further reduced to 1-1/2 to 2 inch size. Any oversize is removed by a vibrating screen at each crusher and recycled. The coke is then conveyed to a bunker from which it is fed by a vibrating feeder to a rotary dryer and dried to less than two per cent moisture. Carbon monoxide recovered from the carbide furnace is used as fuel for drying the coke. The coke is conveyed to a second bunker from which it is fed to a hopper for mixing with lime.

Lime at 90 per cent calcium oxide content from the lime plant is fed to the mixing hopper where it is blended with coke. The lime feed rate would be 475 net tons per day. Coke would be consumed at a rate of 320 net tons per day. Output of calcium carbide on this basis would be 545 net tons per day of 85 per cent purity calcium carbide (CaC_2).

The lime-coke mixture is charged to one of three 35,000 KW Elkem closed rotating furnaces supplied with single phase transformers. Each furnace is equipped with three Söderberg continuous self-baking electrodes. The furnaces are operated at 2000°C to 2200°C. The Söderberg electrodes are charged once per shift with a hot green paste made up from calcined and screened anthracite coal, coal tar pitch (LSP type) and coke fines. The blending of the paste components is performed in a hot-oil, jacketed paddle blender where definite proportions of fine, medium and coarse coal, calcined to remove volatile matter and moisture, are combined with coal tar pitch and coke fines. Carbon monoxide is collected from the furnace, compressed, and distributed to the lime kiln and the coke dryer. Molten calcium carbide is discharged from the furnace directly into one of three copper-steel, seven feet in diameter by one hundred forty feet long water-cooled kiln type coolers. The cooled carbide is crushed to two-inch size by a jaw crusher and to one-quarter inch size by a roller crusher. Any oversize is recycled to the crushers. The crushed carbide is then passed through a magnetic separator to remove ferrosilicon metallic impurities and then is conveyed to a bulk storage bin where it is held under nitrogen for use in acetylene production.

5. Caustic-Chlorine Unit

a. Brine Wells

The brine supply for this plant is expected to be supplied by either of two brine wells located within one-half mile of the plant site of the plant proper. The salt strata is expected to be approximately 7000 feet below grade and the salt bed is to be approximately 100 feet thick. Although there is little danger of subsidence, good practice calls for the brine wells to be located away from the plant proper.

The wells should be located at least 1000 feet apart. In operation, a cavity in the salt strata of up to 200 feet in diameter will be developed at each well. At an appropriate time in operation breakthrough to the adjacent well can be achieved, frequently through the application of hydrostatic pressure to crack the strata.

The salt well consists of an outer casing cemented in place. The operation portion of the well consists of two concentric pipes extending to below the top of the salt strata. The inner pipe extends nearly to the bottom of the salt strata. Water is forced under pressure down the annular space forcing brine up the center pipe. Frequently fuel oil (distillate) is injected with the entering water so as to prevent water contact with the top of the salt strata.

This preserves the upper layer of salt and reduces the frequency of collapse of the rock strata immediately above the salt strata.

Since both the annular space and the inner pipe are flooded with water or brine, the pressure developed to force brine to the surface is only the difference in hydrostatic head between salt brine and water for the depth of the well.

Brine is collected in a steel tank adjacent to the wells to permit recovery of entrained oil. The oil storage and oil injection pumps are usually located adjacent to the well.

The brine is delivered by pipeline to the brine purification section of the chlorine plant.

b. Brine Purification

The brine for a diaphragm cell chlorine plant is purified by chemical addition to remove calcium as calcium carbonate and magnesium as magnesium hydroxide. Only rarely are brines used which are so contaminated with other materials that this type of treatment is not adequate to provide brine of acceptable purity.

Brine from the wells is collected in a single steel storage tank (approximately 300,000 gallons) holding the brine for at least one day of plant operation. From this tank it is transferred by pump to treatment tanks, capable

of treating brine for one day's operation. Treatment chemicals in the form of sodium hydroxide (cell liquor) and sodium carbonate (carbonated cell liquor) are added and the tank contents stirred. It is important that the sludge remaining in the bottom of this tank be mixed thoroughly with the fresh contents. The tank is allowed to stand for a period of 36-48 hours and the pure brine is then decanted through a precoat filter into the pure brine storage tank. This brine should be sparkling clear and contain specific residual amounts of caustic soda and sodium carbonate. After emptying, the treatment tank can be refilled and the operation repeated.

The brine treatment tanks and associated equipment are so sized that one operator can decant and filter one batch of brine and prepare a second batch for settling during one eight-hour shift.

Periodically, the accumulated sludge in the treatment tanks is diluted with water, suspended and flushed to a disposal area. This material does not make good fill and it is important that it not be allowed to discharge into streams or rivers.

c. Cell House

This chlorine plant has been planned to produce 283 tons per day of chlorine and the associated 313 tons of

caustic soda. The cell house will contain 158 Hooker S4 cells operating at 55,000 amperes. These cells may be operated at 60,000 amperes and the production capacity of the plant increased by approximately 9%.

The pure brine is pumped through a brine heater into a brine saturator and cell house head tank. This tank provides uniform head and results in constant flow by gravity to each of the cells.

Each cell consists of a concrete and steel box containing vertical graphite plates surrounded by an iron wire mesh screen supporting an asbestos fiber diaphragm. Brine enters the graphite anode space and is decomposed by the passage of electric current. Chlorine moves to the graphite anode, is discharged and released as chlorine gas rising through the brine and leaving from the cell cover. The sodium ions pass through the asbestos diaphragm and are discharged on the iron wire mesh cathode. Sodium promptly reacts with water at this point and releases hydrogen, forming hydroxyl ions. The hydrogen is confined by the asbestos diaphragm and leaves through a vent in the side of the cell. The sodium and hydroxyl ions leave the cell through an overflow connection from the cathode compartment along with undecomposed salt. This mixture of caustic and salt is called cell liquor.

Chlorine and hydrogen are collected in separate headers for treatment to remove water vapor and entrained liquors. The cell liquor is collected in headers and transferred to the caustic evaporation section.

d. Caustic Evaporation

Caustic evaporation is carried out to achieve two purposes: first, to concentrate the caustic to approximately 50% strength so that it can be shipped economically, and second, to remove and recover the salt which has not been decomposed in the cell. Caustic evaporation is usually carried out in triple effect evaporators to achieve optimum heat economy.

Cell liquor is pumped to the third effect of a triple effect evaporator. This evaporator operates at a pressure corresponding to approximately 26 inches of mercury vacuum with the vapor vented to a barometric condenser. In addition to the cell liquor feed, this evaporator also received salt slurry from the second effect evaporator. This effect is heated by the condensing vapor from the second effect evaporator. Salt slurry is transferred from this effect to the slurry tank of the salt recovery system.

The second effect evaporator is fed by clear liquor decanted from the salt slurry tank of the salt recovery system and with the filtrate from the salt recovery system. In

addition, the second effect receives salt slurry from the first effect evaporator. The second effect is heated by the condensed vapors from the first effect evaporator.

The first effect is heated by condensing steam in an external heat exchanger. Salt slurry is transferred from the first effect to the second effect. Clear liquor is withdrawn from the first effect and circulated through a flash chamber operating at 26 inch vacuum corresponding to the pressure in the third effect and discharged to the caustic cooling system.

The 50% caustic is cooled by exchange with chilled water to approximately 75⁰F. The excess salt separates in form of slimes and is removed in a high speed solid bowl centrifuge. The cool caustic contains approximately 1% of dissolved salt and is stored in a large protected metal storage tank. Since the freezing point of 50% caustic is 60⁰F, this tank contains heating coils.

The salt slurry from the slurry tank is circulated to a solid bowl centrifuge and the filtrate returned to the second effect evaporator. The recovered salt is slurried with salt brine to dissolve traces of sodium sulfate accumulated in the system. This slurry is centrifuged again in a solid bowl machine and collected in a slurry tank for reuse. The brine is reused for sodium sulfate removal until it is

nearly saturated with sodium sulfate. The brine is then discarded.

Equipment in the caustic evaporation and handling system is usually made of nickel to avoid pickup of iron. It is important that the iron content of the finished caustic not exceed more than about six to eight parts per million.

e. Chlorine and Hydrogen

The chlorine collected in the cell house headers is transferred to a titanium tube chlorine cooler. The cool chlorine passes through a brink demister to coalesce the droplets of brine. Chlorine is dried by direct contact with sulfuric acid in two contacting towers arranged in series. Strong sulfuric acid, concentration 93-98%, is used for drying. Droplets of sulfuric acid are removed in a second demister and the chlorine compressed to approximately 150 pounds in three stages by reciprocating compressors. Chlorine is liquified in a chlorine condenser using water as the cooling media.

Hydrogen, collected in the cell house headers, is vented through vertical stacks equipped with steam lines for snuffing fires when they occur.

f. Storage and Shipping

The hydrogen and chlorine will be piped to the vinyl chloride monomer plant for the production of anhydrous hy-

drogen chloride. The bulk of the caustic soda will be marketed.

For this plant, with a production capacity of 283 tons per day of chlorine, we have provided two liquid chlorine storage tanks with a capacity of 500 tons each. These tanks are designed for an operating pressure of 250 psi and are mounted on load cells so that the weight of the contents may be measured directly.

For caustic storage we have provided two storage tanks containing a total of 15 days production of caustic. Caustic shipping facilities provide for the filling of barges, tank trucks, and tank cars.

6. Crude Acetylene Production From Calcium Carbide

Acetylene of 99.5 per cent minimum purity is manufactured from calcium carbide and water in vertical type generators using the "dry" production process. Lime containing six to eight per cent moisture is produced as a by-product. In the proposed plant, calcium carbide of 85 per cent purity is consumed at a rate of 560 tons per day and reaction water is used at about 615 tons per day; acetylene is produced at 190 tons per day and used for monovinyl chloride manufacture; by-product lime, essentially free of acetylene and unreacted calcium carbide, is produced at a rate of about 450 tons per day and is available for

marketing for agricultural and metallurgical use. In the event that markets are not available for the by-product lime, part of the lime would be recycled to the process via the lime kiln, the remaining lime would be purged to control the level of impurities.

Calcium carbide is conveyed from the carbide storage bin to one of two charging hoppers situated above the generator. Each bin is essentially isolated from the generator while it is being loaded with raw carbide. Each bin is nitrogen blown before and after loading. The carbide powder is charged by screw conveyor from each hopper to the top plate of the generator at a rate of 12 tons per hour; water is sprayed onto the top plate at about 3000 to 3200 gallons per hour with the rate adjusted as necessary to obtain maximum acetylene production.

The acetylene generator consists of a vertical cylinder containing eleven horizontal plates and a rotating shaft with four radial arms attached between each plate. The shaft is run at 12 RPM by a 37.5 KW motor. Twelve scraper blades of mild steel on each arm at varying angles move the calcium carbide-water mixture either toward a center plate opening or to the outer edge of the plate where, in both cases, the mixture falls to the plate below. Material moves downward through the unit changing from a slurry

on the top plate to a dry lime powder on the bottom plate. Lime is discharged from the bottom tray of the generator into a steam jacketed hopper. A lime heel is always maintained in the hopper to provide a pressure seal for the acetylene. Steam to the hopper can be regulated so as to adjust the moisture content of the lime. The residual lime is removed at about 9.5 tons per hour by a rotating table type feeder and is conveyed to a filling station where it is packaged for marketing.

Crude acetylene product at 95°C and 950 mm water gage leaves the top of the generator and enters a steel tower where it is water scrubbed to remove entrained lime. The acetylene exit line is equipped with a screw scraper to remove any lime that may be deposited on the walls. A circulating pump recycles lime water at 10 to 12 thousand gallons per hour to the tower; fresh water is added at 3000 to 4000 gallons per hour. Excess lime water is sent to lime ponds. A safety seal set at 1500 mm water gage is located prior to the entrance of acetylene to the tower.

Acetylene leaves the scrubber at 87°C and enters a cooling tower packed with 1-1/4 inch steel Raschig rings. Acetylene is cooled to 35°C by water at 30°C sprayed over the tower at a rate of 10 to 12 thousand gallons per hour;

makeup water of 3000 to 4000 gallons per hour is consumed. Liquid effluent from the bottom of the tower is recirculated by a pump to the top of the tower through an iron heat exchanger. Excess water is sent to ponds. The acetylene from the cooling tower passes through a "safety bottle" (a water seal to prevent flash back in case of ignition) into a gas holder after which the pressure is 45 mm mercury gage. The rate of acetylene production is about eight tons per hour for the plant.

7. Vinyl Chloride Manufacture

a. Acetylene Purification

Crude acetylene from the acetylene plant gas holder is compressed to 15 psig by a Roots-Connersville sliding vane type blower at a rate of four net tons per hour or 110 thousand standard cubic feet per hour per line. Two purification lines are employed to process approximately 190 net tons of gas per day. The compressed gas is passed into a mild steel rubber-lined tower, six feet diameter by 36 feet, packed with 1-1/4 inch porcelain Raschig rings. Here, the acetylene is scrubbed by a countercurrent stream of ten per cent sulfuric acid circulated over the tower at a rate of 6,600 gallons per hour. The acid is replaced when its concentration falls to one to four per cent, or, becomes badly discolored and fouled with resinous reaction products.

Ammonia as ammonium sulfate is removed at this point.

The acetylene stream from the top of the sulfuric acid scrubber is passed into the bottom of a second tower of mild steel construction, six feet diameter by 36 feet, packed with 1-1/4 inch steel Raschig rings. The gas is scrubbed with a counter-current stream of sodium hypochlorite solution containing 1.20 to 1.30 grams of free chlorine per liter. The solution is recycled over the tower at a rate of 6,000 gallons per hour with a continuous purge and addition of fresh solution maintained. Phosphine, arsine and silane are removed here. The hypochlorite solution is prepared in the purification plant using caustic and chlorine from the caustic-chlorine plant.

The acetylene stream is now passed into the bottom of a third tower of mild steel construction, six feet diameter by 36 feet, packed with 1-1/4 inch steel Raschig rings where it is scrubbed by a counter-current stream of ten per cent caustic solution. Caustic is passed over the tower at a rate of 6,000 gallons per hour, a continuous purge is maintained and fresh feed is added at a rate of 100 gallons per hour. The caustic solution is recycled until it becomes greatly discolored and contains a high insoluble matter content. The caustic serves to remove carbon dioxide, hydrogen sulfide, organic sulfides, aldehydes and acids.

Caustic is obtained from the caustic-chlorine plant.

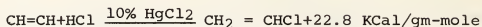
Acetylene from the caustic scrubber is passed into the bottom of a fourth mild steel tower, six feet diameter by 36 feet, packed with 1-1/4 inch steel Raschig rings in which it is water-scrubbed to remove any salts that may be present. Water is sprayed over the tower at a rate of 6,000 gallons per hour, a continuous purge is maintained and fresh water is added at a rate of 100 gallons per hour.

The acetylene discharge stream from the water scrubber at about 30°C is passed through a brine cooler and cooled to -10°C. Contained moisture is condensed here and removed in a separator. The gas stream is then passed into a bank of three 10 feet by 10 feet mild steel towers connected in series with each containing a bed of approximately seven net tons of activated carbon. The activated carbon beds are water cooled. Normal operation of these towers will have two towers in service and one on a reactivation cycle. The carbon is reactivated with superheated steam. The activated carbon provides a polish purification for the acetylene removing trace amounts of impurities. The purified gas then passes into a gas holder from which it is fed to the vinyl chloride operation.

b. Vinyl Chloride Monomer

Monovinyl chloride is prepared by reaction of acety-

lene and hydrogen chloride in the vapor phase in the presence of activated carbon impregnated with mercuric chloride catalyst.



The exothermic reaction is carried out in steel fixed-bed multitubular vessels with temperature controlled by circulation of Dowtherm coolant and regulation of the gas flow rates. The crude monomer is scrubbed with water and caustic and is then liquified and fractionally distilled to obtain the pure product.

Purified acetylene at 8.2 tons or 227,000 standard cubic feet and dry hydrogen chloride at 11.5 tons or 238,000 standard cubic feet per hour are blended in a primary mixer. A five to ten per cent excess of hydrogen chloride is used in order to obtain complete conversion of the acetylene. The gas mixture is then dehumidified by passing the stream through a Karbate heat exchanger using calcium chloride brine at -20°C . Any condensate is removed in a separator. The dry gas mixture then passes through a secondary mixing chamber and then into the top of the reactor under the suction of a blower after the reactor.

The acetylene is obtained from the purification plant gas holder. The hydrogen chloride is obtained by burning 8.0 tons per day of hydrogen and 283 tons per day of

chlorine from the caustic-chlorine plant. The hydrogen chloride synthesis plant consists essentially of chlorine burners, necessary control and safety devices and hydrogen chloride processing facilities. The burners consist of two concentric steel tubes with chlorine passing through the inner tube and the hydrogen through the annulus. A one per cent excess of hydrogen is used to insure complete combustion of the chlorine in the combustion chamber. A retractable torch using an air-hydrogen flame is used to ignite the mixture. An explosion diaphragm is provided in the burner body; an ignition device is provided in the outlet duct to prevent the delivery of an explosive mix in place of hydrogen chloride; automatic gas shut-offs and liquid seals are provided in the event of failure of the gas supply and to prevent "suck-back" of the reactants. The burner is also provided with a carbon dioxide purge system for use when a shutdown occurs. In the proposed plant, ten vertical cylindrical burner units of mild steel brick-lined construction, four feet I.D. by 15 feet high would be required for 290 net tons per day of hydrogen chloride gas.

The hydrogen chloride gas from the burners containing about 0.6 per cent hydrogen, 0.1 per cent water vapor and 0.3 to 1.3 per cent inerts is passed through a water submerged bank of Karbate tubes where the gas is cooled from

about 2000°F to 100°F. Gas streams from two burner units are combined at this point. Condensate from the coolers is drained to a rubber-lined trap and pumped to a 36 per cent acid storage tank at a rate of about 200 gallons per day. The cooled gases pass to the top of a counter-current falling film type of absorber where the hydrogen chloride is absorbed in 20 per cent hydrochloric acid (HCl). The 20 per cent hydrochloric acid is passed over the tower at a rate of 7,000 gallons per hour with the rate regulated so as to obtain a 36 per cent hydrochloric acid. The tail gases pass to a Karbate tower packed with 1-1/4 inch porcelain Raschig rings where vent gases are scrubbed with 20 per cent hydrochloric acid. A steam-operated evacuator in the tail gas scrubber exhausts the non-condensable gases, including hydrogen, to the atmosphere, through vertical stacks equipped for snuffing fires when they occur.

The 36 per cent hydrochloric acid at 80°F to 90°F is pumped to a rubber-lined storage tank. From the storage tank, the 36 per cent hydrochloric acid is pumped to a packed Karbate tower stripper equipped with a Karbate tube reboiler heated with 50 psig steam. The stripper is operated at 30 psig. The hydrogen chloride enriched gases leave the tower at 71°C to 77°C and the 20 per cent stripped

acid leaves from the bottom at 132°C . The weak acid passes through a Karbate cascade cooler to a rubber-lined storage tank. This 20 per cent hydrochloric acid is then recycled to the absorber. The stripper gases enter a series of vapor condensers, the top condensers being water-cooled and the bottom condenser being cooled with refrigerated brine to a temperature of from -18°C to -15°C . The hydrogen chloride gas is cooled to -13°C to -12°C , effectively drying the gas. The condensate from the condensers is returned to the 36 per cent hydrochloric acid storage. The hydrogen chloride gas is passed through a fiber glass packed mist separator and then on to the monovinyl chloride process at 12 psig. In the proposed plant, five hydrogen chloride absorption-desorption purification lines would be utilized to process 290 net tons per day of gas using common storages for the 20 per cent and 36 per cent acids.

The monovinyl chloride reactor consists of 600 tubes of 3-1/8 inch diameter and ten feet in length filled with mercuric chloride impregnated activated carbon of approximately ten mesh particle size. The catalyst is prepared by stirring activated charcoal in a rubber-lined vessel with sufficient mercuric chloride solution to give a dry catalyst containing ten per cent by weight of the

salt. The catalyst is dried at 80°C to 100°C until it is moisture-free. The catalyst in the reactor rests on a bed of non-impregnated activated carbon which is placed below the bottom tube plate before the catalyst is charged. The catalyst charge per reactor is about three tons. The life of the catalyst is approximately five months with about one ton of catalyst consumed per 250 tons of monomer. At startup of the reactor with fresh catalyst, the catalyst is saturated with hydrogen chloride. The catalyst bed is warmed to initiate the reaction by circulation of Dowtherm on the shell side of the reactor. After initiation, the Dowtherm is used as a coolant. The acetylene at startup is introduced at a low flow rate and increased slowly to avoid overheating the catalyst. The reactors are operated in parallel except when a reactor is near the end of its life. At this time, a newly charged reactor is put in series behind it. The reactors operate in the range of 138°C to 204°C (280°F to 400°F) and one atmosphere absolute pressure. The temperature at the center of the bed is held at 220°C (430°F) maximum. The temperature in the reactor is allowed to rise as the catalyst becomes spent; use of Dowtherm as a heating agent may be required toward the end of the catalyst's life. At the end of the catalyst's life,

i.e., when the acetylene (C_2H_2) content in the exit gas reaches two per cent, it is removed from the tubes by suction in an air stream after flushing the reactor with dry nitrogen. The mercury content in the carbon is reclaimed by roasting, and the carbon is discarded. The exit gas from the reactor normally consists of 90 to 92 per cent of monovinyl chloride, 0.05 to 1.0 per cent acetylene, and seven to nine per cent hydrogen chloride. The balance of the stream is made up of inerts and other chlorinated products. Conversion to monomer based upon acetylene is 95 to 96 per cent. In the proposed 450 net tons per day plant, ten banks of reactors with nine reactors per bank are required.

The exit gases from two banks of reactors are combined in a rubber-lined steel pipe and conveyed to a series of three rubber-lined mild steel towers packed with 1-1/4 inch porcelain Raschig rings. In the first two towers, the gas is scrubbed by a counter-current stream of water passed over the towers at a rate of 7,000 gallons per hour. The bulk of the hydrogen chloride and inerts are removed at this point. In the third tower a ten per cent caustic solution is passed over the unit at a rate of 7,000 gallons per hour to remove the remaining hydrogen chloride, carbon

dioxide and aldehydes which will inhibit the polymerization reaction. The caustic is obtained from the caustic-chlorine plant. A continuous purge is maintained and fresh feed is added at a rate of 200 gallons per hour.

The neutralized crude gas from the caustic scrubber is then cooled to about -10°C by counter-current washing with 30 per cent calcium chloride in a rubber-lined mild steel tower packed with 1-1/4 inch porcelain Raschig rings. The gas enters at the middle of the tower and leaves from the top. The gas stream then passes through a separator where condensed moisture is removed. The monovinyl chloride is then passed through a rubber-lined steel tower containing a silica gel bed for complete drying. At this point the gas contains 0 to 1 per cent acetylene, the hydrogen and nitrogen originally in the gas, and about 1 per cent, ethylidene dichloride and other high boiling fractions.

The crude monomer is again cooled to about -10°C in a brine cooler and sent to a topping column of mild steel construction. The top of the column is refluxed with liquid vinyl chloride and the bottom is heated to about 30°C by circulating glycol. The bottoms fraction is removed and worked up in a batch still for recovery of the ethylidene chloride. The vinyl chloride and gases leave the top of the

column and most of the monomer is condensed in a brine cooler. The uncondensed gas is further cooled to -70°C by means of ammonia coils in a backward return condenser. A part of the liquid monomer returns to the topping column as reflux. The balance of the vinyl chloride goes to the center of a degassing column where vinyl chloride is heated to -13°C at the bottom of the column while acetylene leaves at the top. The pure monomer is tapped from the bottom of the column, cooled to -40°C by calcium chloride brine and transferred to a storage using compressed nitrogen. The steel storage tank is held at -40°C by circulating calcium chloride brine through a cooling coil in the vessel. In the proposed plant, five purification lines will be required to process 450 net tons per day of monomer.

NOTE: Inhibitors, such as phenol, tert-butyl catechol and hydroquinone in concentrations of 50 to 500 ppm, are normally added to the monomer stocks to insure stability. The inhibitor would be removed prior to polymerization to polyvinyl chloride by caustic scrubbing or distillation. It is believed that addition of inhibitor to monomer produced in the proposed plant is unnecessary as the product is stored at -40°C and would be consumed in polyvinyl

chloride manufacture at a relatively rapid rate. Shipments of pure monomer would perhaps require inhibitor addition although it was reported in the literature that tank car shipments of unstabilized monomer were made in Germany during World War II.

8. Polyvinyl Chloride Manufacture

Pure vinyl chloride monomer from storage is transferred at a rate of 450 tons per day to the polymerization plant. Polyvinyl chloride is produced at a rate of 430 tons per day assuming a 95 per cent conversion to polymer and a 96 per cent over-all yield for the process.

The polymerization reaction is carried out in a 4,000 gallon glass-lined jacketed vessel equipped with a glass-lined agitator and Duroseals on the agitator shafts. The reactors are also fitted with reflux condensers for additional temperature control. The reaction makeup consists of monomer, deionized water, a suspension agent and a suitable catalyst. Organic peroxide catalysts, such as benzoyl and acetyl peroxides which are monomer soluble, are used for suspension polymers while inorganic water soluble catalysts such as hydrogen peroxide and persulfates are used for emulsion polymerized resins. One of the primary differences between suspension and emulsion polymers is in the particle size of the resins. Suspension

polymerized resins have a particle size distribution in the range - 100 to +325 mesh; emulsion polymerized resins are made up of small particles that remain in colloidal suspension and are considered latexes. Forming agents, such as sodium laurysylsulfate and sodium alkylbenzenesulfonate (soap solutions) are also used in emulsion polymerizations. It is assumed that suspension polymerization will be the primary process employed at the proposed plant.

Batch makeup formulations will vary depending upon the desired product. The ratio of monomer to deionized water can fluctuate over a wide range with the limiting factor being sufficient fluidity of the polymer-water slurry to permit adequate dissipation of the heat evolved during the reaction. For the proposed plant, a formulation consisting of 110 parts monomer, 100 parts deionized water, 0.2 part benzoyl peroxide catalyst and 0.1 part polyvinyl alcohol suspension agent was used as a basis for input-output calculations. In addition, to prevent a pH drop during polymerization due to formation of hydrochloric acid, 0.1 part sodium carbonate is added. Other alkaline buffers such as sodium bicarbonate or sodium phosphate can also be used to hold pH at 5-8. In terms of quantities, 1900 gallons or 7.8 tons of monomer and 1700 gallons or 7.1 tons of deionized water are metered in to the reactor. Then, 30

pounds of benzoyl peroxide, 15 pounds of polyvinyl alcohol and 15 pounds of sodium carbonate are added. An inert nitrogen atmosphere is maintained in the reactor during polymerization to increase the rate of reaction and reduce hydrochloric acid formation. The reactants are brought to the desired polymerization temperature which may vary from 38°C to 71°C at 80 to 180 psig depending upon the product desired. The temperature of the exothermic reaction is controlled at $\pm 0.3^{\circ}\text{C}$ to maintain uniform quality. The reaction time will range from 12 to 18 hours.

The molecular weight of the polymers produced is inversely proportional to the reaction temperature and catalyst concentration. In addition, as molecular weight increases, the polymers become less brittle, tougher and more extensible. It should be realized, therefore, that batch makeup and operating conditions may have to be altered in order to achieve a satisfactory balance between polymerization rate and desired product characteristics.

Deionized water is prepared by treatment of raw water with lime and alum, filtration in a pressure filter packed with a powdered coal bed, and passage through a series of two ion-exchange units. The treated water is held in two 25,000 gallon aluminum storage tanks. As a final purification step, the water is heated to remove carbon dioxide and

oxygen, which retards the polymerization reaction, and then is charged to the reactors using 135 psig centrifugal pumps.

Upon completion of the reaction, the batch is dropped to a 12,000 gallon glass-lined agitated tank through self-cleaning, water-flushed dump valves. This vessel is used to remove unreacted monomer and accommodates three polymerization batches. A reciprocating compressor operating as a vacuum pump maintains a 27-28 inch vacuum for one to three hours and the monomer is removed by vaporization from the polymer-water mixture. The vinyl chloride monomer is compressed to 80 psig and recycled to the monomer treatment plant for purification.

After completion of residual monomer removal, the polymer suspension is transferred to 15,000-gallon, resin-lined surge tanks. The surge tanks feed the spray drying systems and the continuous discharge centrifuges which, in turn, feed the rotary drying systems. In the centrifuges, the polymer is dewatered, washed and dewatered again to about 25 per cent moisture content.

Polymer slurry to be spray dried is fed directly to the dryer cone without dewatering. The dryer unit is 18 feet in diameter at the top of the cone and three stories high. It is operated at 121°C (250°F). Dried resin from the cone bottom is screened to remove oversize and then is

packaged in bags or transported by conveyor to bulk storage. Oversize is passed through a mill for particle reduction and then is recycled over the screen. The dryer system is equipped with a vibrating bag type dust collector to remove resin dust from the air stream before discharge to the atmosphere. The output for the dryer is 4.5 tons per hour. Two dryer units are required assuming that 50 per cent of the plant output will be spray dried.

Dewatered resin from the centrifuges flow by gravity to an 8 foot diameter by 50 foot long rotary dryer. The dryer is operated at 135°C (275°F) and is heated by a counter-current air stream. Again, the dried resin is screened and the oversize milled and recycled. The product is either bagged or conveyed to bulk storage. The primary difference between the spray and rotary dried materials is in particle size, i.e., spray dried product is less than 325 mesh and rotary dried polyvinyl chloride is about 140 mesh particle size. Various mesh cuts can be obtained by suitable combinations of screening and grinding operations.

Air used in the drying systems is passed through an oil-film air filter and an electrostatic precipitator which removes the last trace of impurities in the air stream. In addition, magnetic separators are located on wet and dry polymer streams in order to pick up any iron that may be

present. Syntron vibrators are also affixed to discharge and feed hoppers to prevent bridging and caking of the resin.

B. PROJECT DESCRIPTION OF KUREHA NAPHTHA CHLORINE PVC PLANT AT REESEDAL

A facility to produce 300 million pounds per year PVC from naphtha in southwestern Pennsylvania at Reesedale would receive naphtha by barge when the Ohio-Allegheny River is navigable and by rail at those times during freeze and flood when the barge transport is not possible. Bituminous coal, used as fuel for the steam boilers, would be received by truck or rail. The brine supply for this plant would be provided by local artificial brine wells and delivered by pipeline to the brine purification section of the chlorine plant.

The caustic-chlorine facility and the PVC plant for this plant would be essentially the same as described for the carbide-acetylene plant in Paragraph A of this Appendix. The only point of difference would be that hydrogen collected from the Hooker caustic-chlorine cells would be used for fuel rather than employed as an intermediate raw material.

The manufacture of vinyl chloride would be accomplished from naphtha and chlorine by the Kureha Process, which is described in Hydrocarbon Processing, 43 (11) 165 - 170 (November 1964). A brief description follows:

1. Naphtha Cracking

Naphtha is preheated to about 500°C and is injected into a burner for cracking. Process off-gas burned to over 2000°C is mixed with naphtha in the burner. The mixed gases then pass to the burner reaction chamber where the naphtha is thermally cracked at atmospheric pressure. The proportion of acetylene to ethylene is carefully controlled. A water scrubber is used to remove carbon and tarry matter, the cracked gas is then sent to a cracked gas holder.

2. Cracked Gas Purification

A multistage compressor is used to compress the cracked gas to seven atmospheres and to cool gas below -20°C, thus removing water and aromatics, including by-product benzene. The gas is sent to an absorber and stripper for removal of higher hydrocarbons.

3. Acetylene Reaction

Purified cracked gas is mixed with hydrogen chloride and reacted in an acetylene reactor to yield vinyl chloride. The acetylene is the cracked gas in continuously analyzed and the hydrogen chloride is added at a rate of 96 to 98 per cent of the stoichiometric quantity required for a complete reaction. The catalyst bed of mercuric chloride is kept between 120°C and 180°C. The reaction yield of vinyl chloride is between 95 and 98 per cent based on acetylene

and over 99 per cent based on hydrogen chloride. The reaction is carried out under pressure with the partial pressure of the acetylene below 0.6 atmospheres. The side reactions are negligible.

Vinyl chloride is extracted from the reacted gases via an absorber and stripper using ethylene dichloride as the solvent. All vinyl chloride produced by this process leaves the top of the stripper, whether produced from the acetylene or from ethylene dichloride.

Vinyl chloride leaving the stripper is sent to purification unit for removal of ethylene dichloride and other impurities by distillation. The vinyl chloride produced by this process is of satisfactory quality for the production of polyvinyl chloride.

4. Production and Purification of Ethylene Dichloride

The cracked gas after purification and subsequent removal of acetylene as vinyl chloride passes to the ethylene reactor where chlorine reacts with the ethylene to form ethylene dichloride. The reaction, which is catalyzed by ferric chloride, takes place in a solvent of ethylene dichloride. The amount of chlorine fed to the reactor is between 96 and 98 per cent of the stoichiometric quantity required for a complete reaction with the ethylene. The amount of chlorine is limited to avoid explosive reaction of excess chlorine with the hydrogen contained in the

cracked gas. The chlorination of ethylene is carried out at a pressure of four to five atmospheres and cooling water is used to maintain the temperature between 50°C and 70°C. Side reactions are few and the yield based on chlorine is about 99 per cent.

The cracked gas from which the ethylene and acetylene have been removed, process off-gas, is available for use as a fuel for naphtha cracking, ethylene dichloride cracking and also for a portion of boiler fuel requirements.

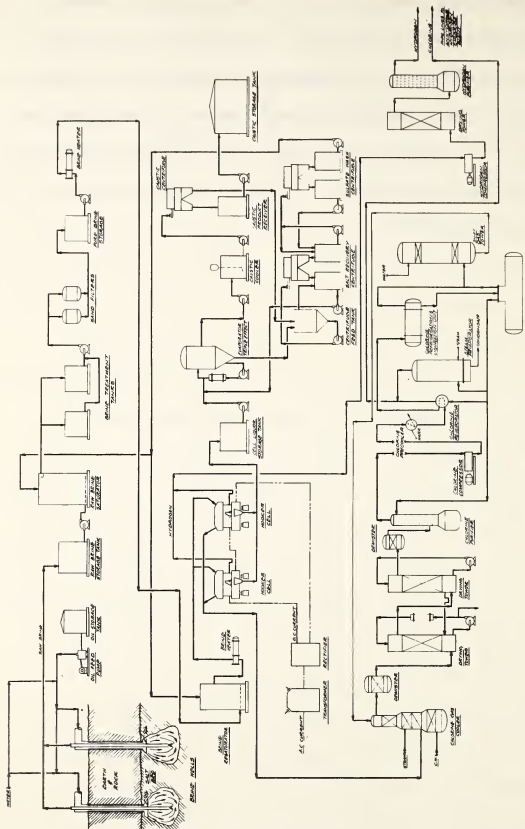
Two distillation columns are used to purify the ethylene dichloride prior to thermal cracking.

5. Thermal Cracking of Ethylene Dichloride

Vaporized ethylene dichloride is thermally cracked as it flows through the tubes of the cracking furnace. The cracking takes place at seven atmospheres and at 450°C to 550°C. The yield of vinyl chloride based on cracked ethylene dichloride passing through the furnace is cracked.

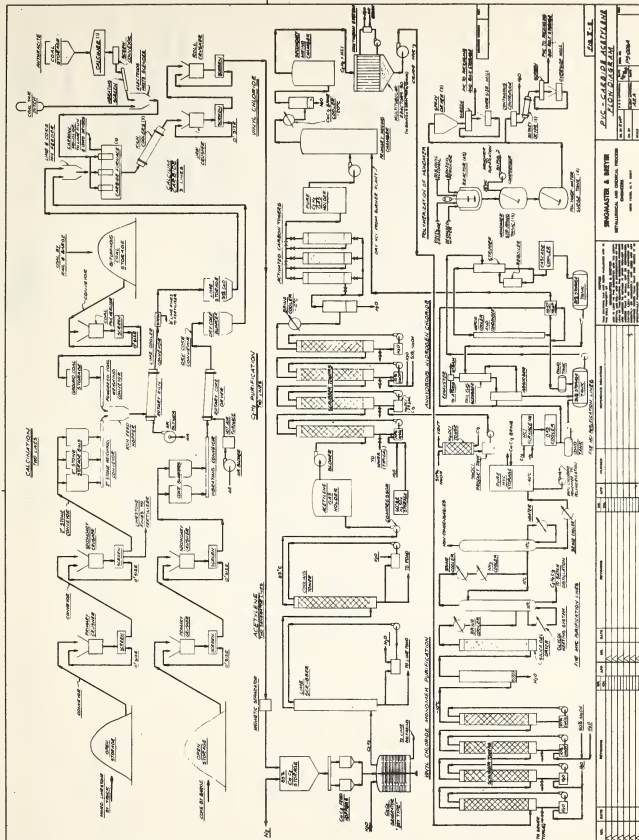
The gas mixture leaving the furnace contains vinyl chloride, hydrogen chloride, unreacted ethylene dichloride and small amounts of tar and carbon. The tar and carbon are removed by cooling and partial condensation. The gas mixture is sent to a hydrogen chloride tower for removal of the hydrogen chloride, which is sent to the acetylene reactor. The remaining mixture of vinyl chloride and

ethylene dichloride goes to the vinyl chloride removal section previously mentioned. A portion of the ethylene dichloride solvent is continuously removed from the absorber to balance the unreacted ethylene dichloride entering the absorber with the vinyl chloride. The ethylene dichloride removed from the absorber is sent to the ethylene dichloride distillation section.



CONSULTING ENGINEER

SHEET NO.		SHEET TOTAL		DATE		BY		CHECKED		APPROVED		
1	1	1	1	1	1	1	1	1	1	1	1	
<p>SYNOPSIS & ANALYSIS</p> <p>SYNOPSIS: This process is designed to produce a high-purity product from a feed stream containing various impurities. The process involves several stages of distillation and separation, followed by a final purification step.</p> <p>ANALYSIS: The feed stream is analyzed for its composition, including the main components and the levels of various impurities. The analysis is used to determine the optimal operating conditions for the process.</p>												
NO.	DESCRIPTION	UNIT	TYPE	SIZE	NO.	DESCRIPTION	UNIT	TYPE	SIZE	NO.	DESCRIPTION	
1	Feed Tank	T-1	Storage	1000 gal	11	Distillation Column	D-1	Distillation	48" dia	12	Condenser	C-1
2	Distillation Column	D-2	Distillation	48" dia	13	Reboiler	R-1	Reboiling	36" dia	14	Storage Tank	T-2
3	Condenser	C-2	Condensing	36" dia	15	Distillation Column	D-3	Distillation	48" dia	16	Condenser	C-3
4	Reboiler	R-2	Reboiling	36" dia	17	Distillation Column	D-4	Distillation	48" dia	18	Condenser	C-4
5	Storage Tank	T-3	Storage	1000 gal	19	Distillation Column	D-5	Distillation	48" dia	20	Condenser	C-5
6	Distillation Column	D-6	Distillation	48" dia	21	Reboiler	R-3	Reboiling	36" dia	22	Storage Tank	T-4
7	Condenser	C-6	Condensing	36" dia	23	Distillation Column	D-7	Distillation	48" dia	24	Condenser	C-7
8	Reboiler	R-4	Reboiling	36" dia	25	Distillation Column	D-8	Distillation	48" dia	26	Condenser	C-8
9	Storage Tank	T-5	Storage	1000 gal	27	Distillation Column	D-9	Distillation	48" dia	28	Condenser	C-9
10	Distillation Column	D-10	Distillation	48" dia	29	Reboiler	R-5	Reboiling	36" dia	30	Storage Tank	T-6



200-1-1

DESIGN & CONSTRUCTION

BRUNNEN & MEYER

REPRESENTATION AND GENERAL PROCESS

100% A, 5% B

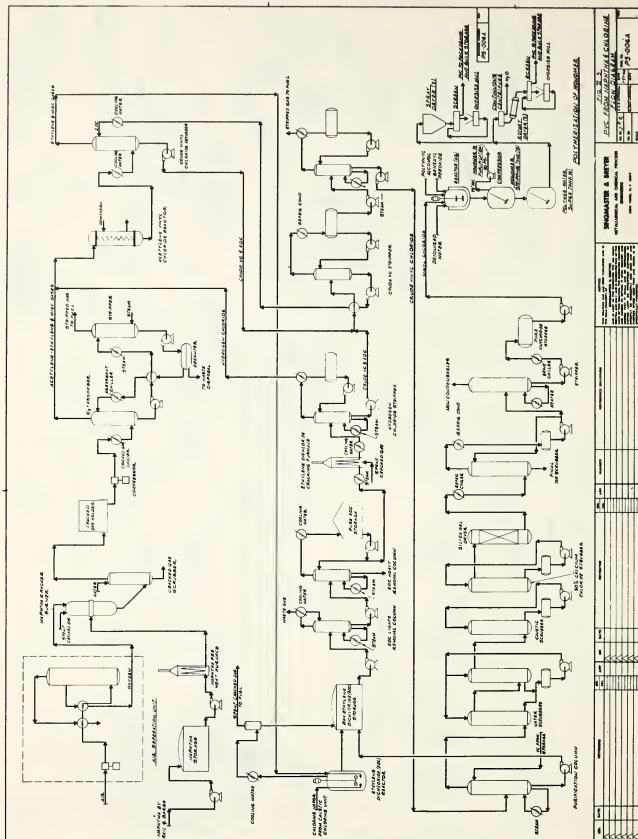
100% A, 5% B

100% A, 5% B

100% A, 5% B

100% A, 5% B

100% A, 5% B



SHEET NO. 1										SHEET NO. 2										SHEET NO. 3										SHEET NO. 4										SHEET NO. 5										SHEET NO. 6										SHEET NO. 7										SHEET NO. 8										SHEET NO. 9										SHEET NO. 10															
<p>2,4-DICHLOROPHENOL</p> <p>PROCESS FLOW SHEET</p> <p>UNIT: TONS PER DAY</p> <p>DATE: 1967-01-01</p> <p>DESIGNED BY: J. H. HARRIS</p> <p>CHECKED BY: J. H. HARRIS</p> <p>APPROVED BY: J. H. HARRIS</p> <p>REVISIONS:</p> <table><tr><th>NO.</th><th>DATE</th><th>DESCRIPTION</th></tr><tr><td>1</td><td>1967-01-01</td><td>Initial Design</td></tr></table>																																																																																																				NO.	DATE	DESCRIPTION	1	1967-01-01	Initial Design
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